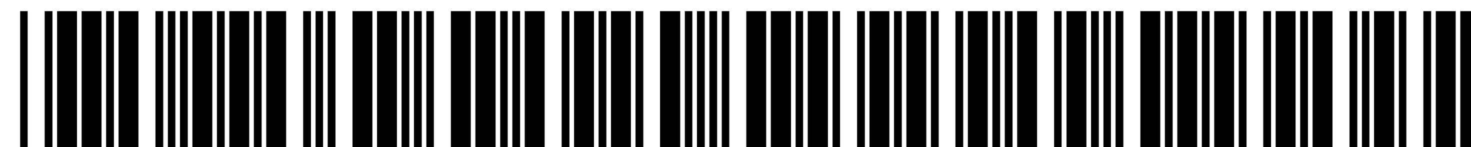
US009508894B2

(12) **United States Patent**
**Lu et al.**

(10) **Patent No.:** **US 9,508,894 B2**
(45) **Date of Patent:** **Nov. 29, 2016**

(54) **METHOD OF SELECTIVELY TRANSFERRING SEMICONDUCTOR DEVICE**

(71) Applicant: **EPISTAR CORPORATION**, Hsinchu (TW)

(72) Inventors: **Chih-Chiang Lu**, Hsinchu (TW); **Yi-Ming Chen**, Hsinchu (TW); **Chun-Yu Lin**, Hsinchu (TW); **Ching-Pei Lin**, Hsinchu (TW); **Chung-Hsun Chien**, Hsinchu (TW); **Chien-Fu Huang**, Hsinchu (TW); **Hao-Min Ku**, Hsinchu (TW); **Min-Hsun Hsieh**, Hsinchu (TW); **Tzu-Chieh Hsu**, Hsinchu (TW)

(73) Assignee: **EPISTAR CORPORATION**, Hsinchu (TW)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/908,886**

(22) PCT Filed: **Jul. 29, 2013**

(86) PCT No.: **PCT/CN2013/080335**

§ 371 (c)(1),
(2) Date: **Jan. 29, 2016**

(87) PCT Pub. No.: **WO2015/013864**

PCT Pub. Date: **Feb. 5, 2015**

(65) **Prior Publication Data**

US 2016/0163917 A1 Jun. 9, 2016

(51) **Int. Cl.**

***H01L 33/62*** (2010.01)
***H01L 33/00*** (2010.01)
***H01L 21/683*** (2006.01)

(52) **U.S. Cl.**

CPC ....... ***H01L 33/0095*** (2013.01); ***H01L 21/6835*** (2013.01); ***H01L 21/6836*** (2013.01); ***H01L 33/0079*** (2013.01); ***H01L 33/62*** (2013.01); *H01L 2221/68318* (2013.01); *H01L 2221/68363* (2013.01); *H01L 2221/68381* (2013.01); *H01L 2933/0066* (2013.01)

(58) **Field of Classification Search**

None
See application file for complete search history.

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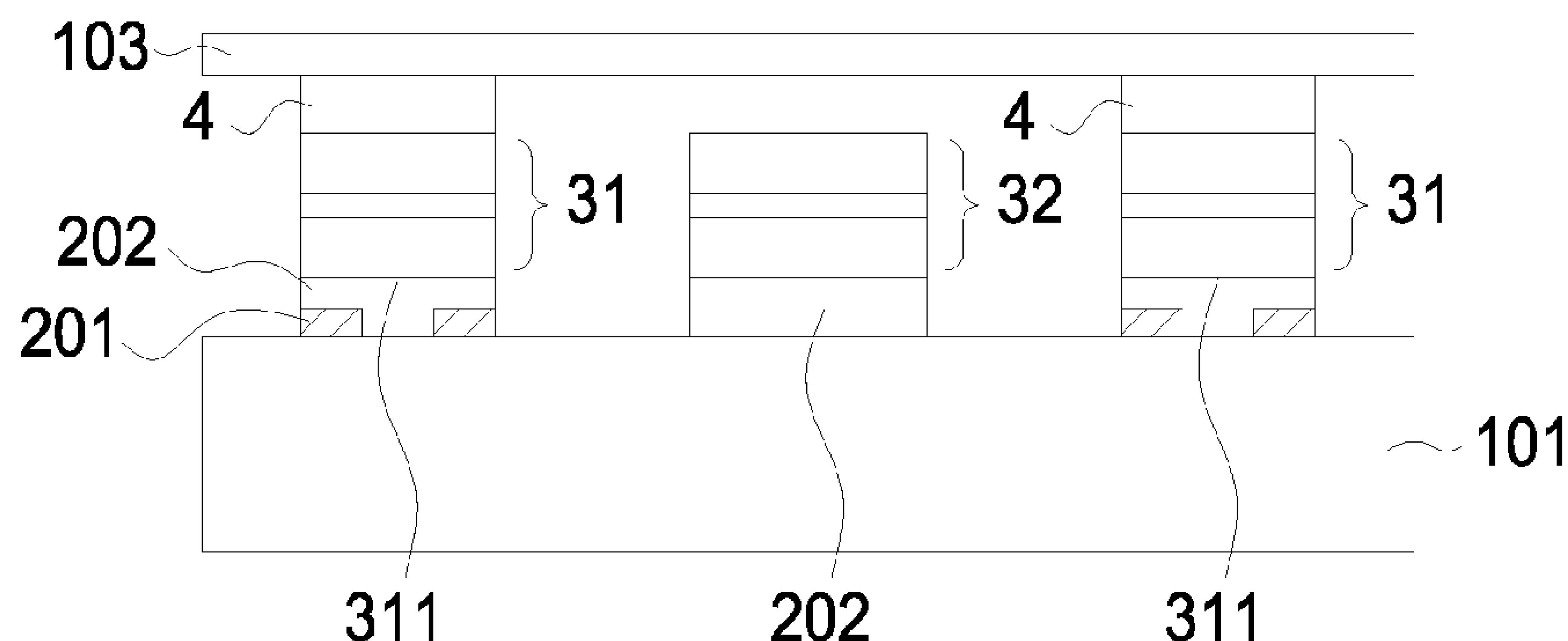
*Primary Examiner* — Alexander Ghyka

(74) *Attorney, Agent, or Firm* — Muncy, Geissler, Olds & Lowe, P.C.

(57) **ABSTRACT**

A method of selectively transferring semiconductor devices comprises the steps of providing a substrate having a first surface and a second surface; providing a plurality of semiconductor epitaxial stacks on the first surface, wherein each of the plurality of semiconductor epitaxial stacks comprises a first semiconductor epitaxial stack and a second semiconductor epitaxial stack, and the first semiconductor epitaxial stack is apart from the second semiconductor epitaxial stack, and wherein a adhesion between the first semiconductor epitaxial stack and the substrate is different from a adhesion between the second semiconductor epitaxial stack and the substrate; and selectively separating the first semiconductor epitaxial stack or the second semiconductor epitaxial stack from the substrate.

**43 Claims, 23 Drawing Sheets**



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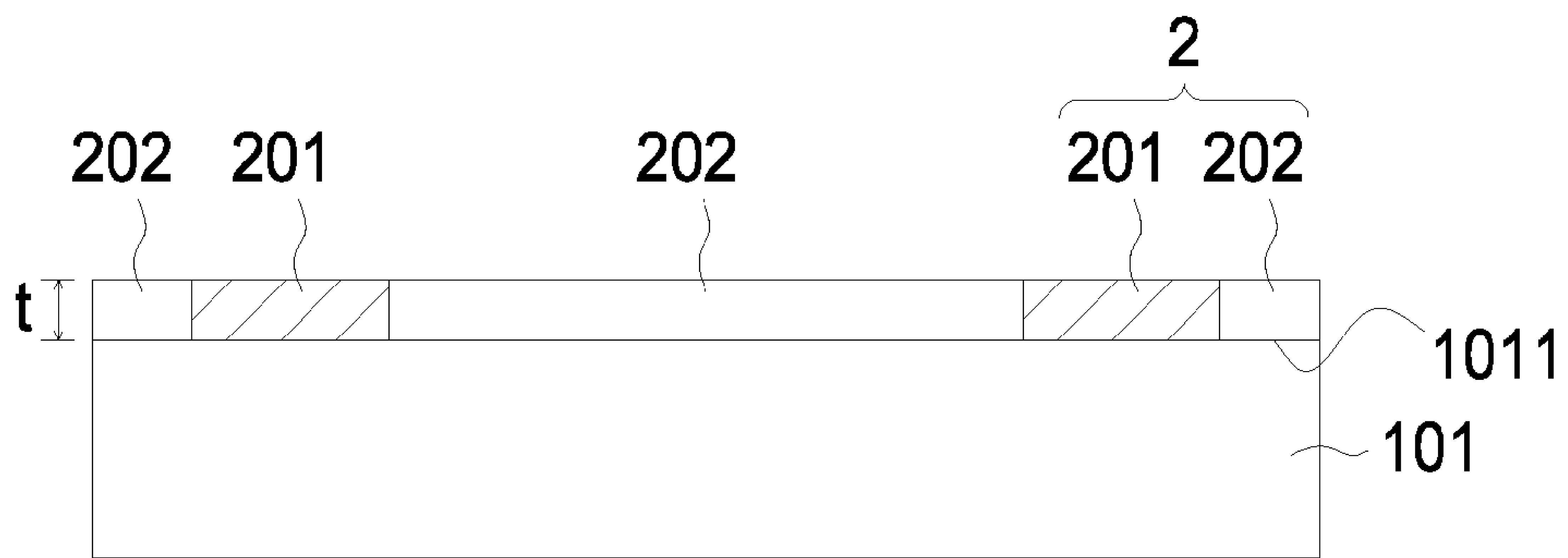



FIG. 1A

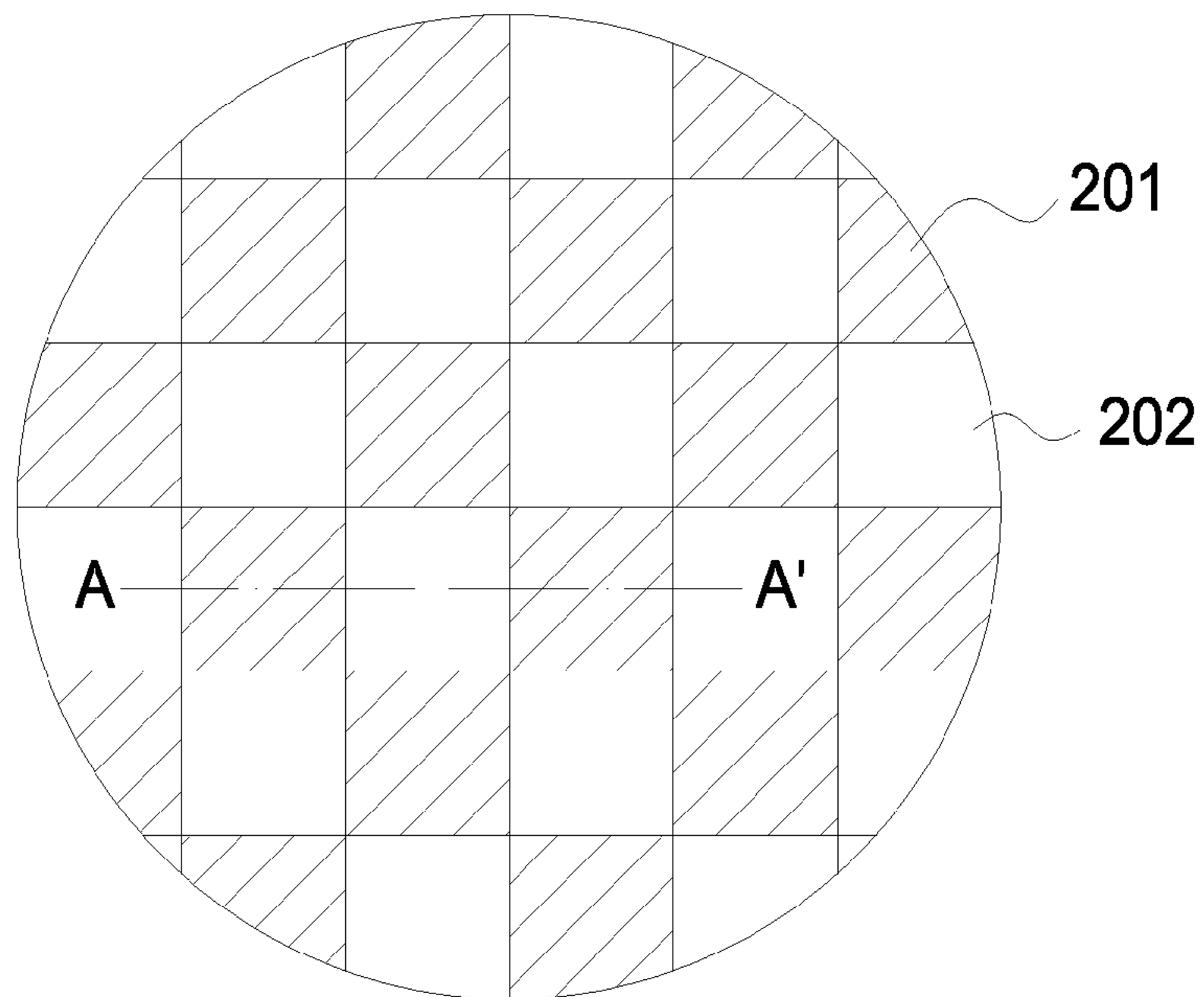



FIG. 1B

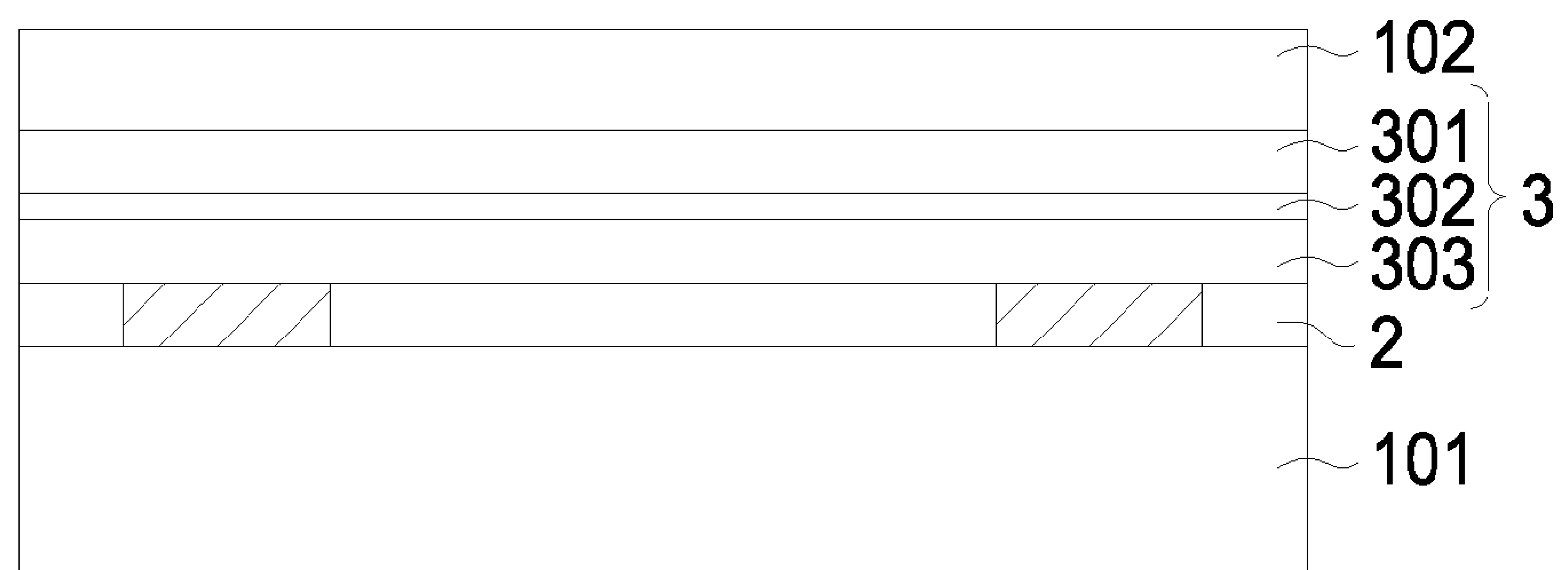



FIG. 1C

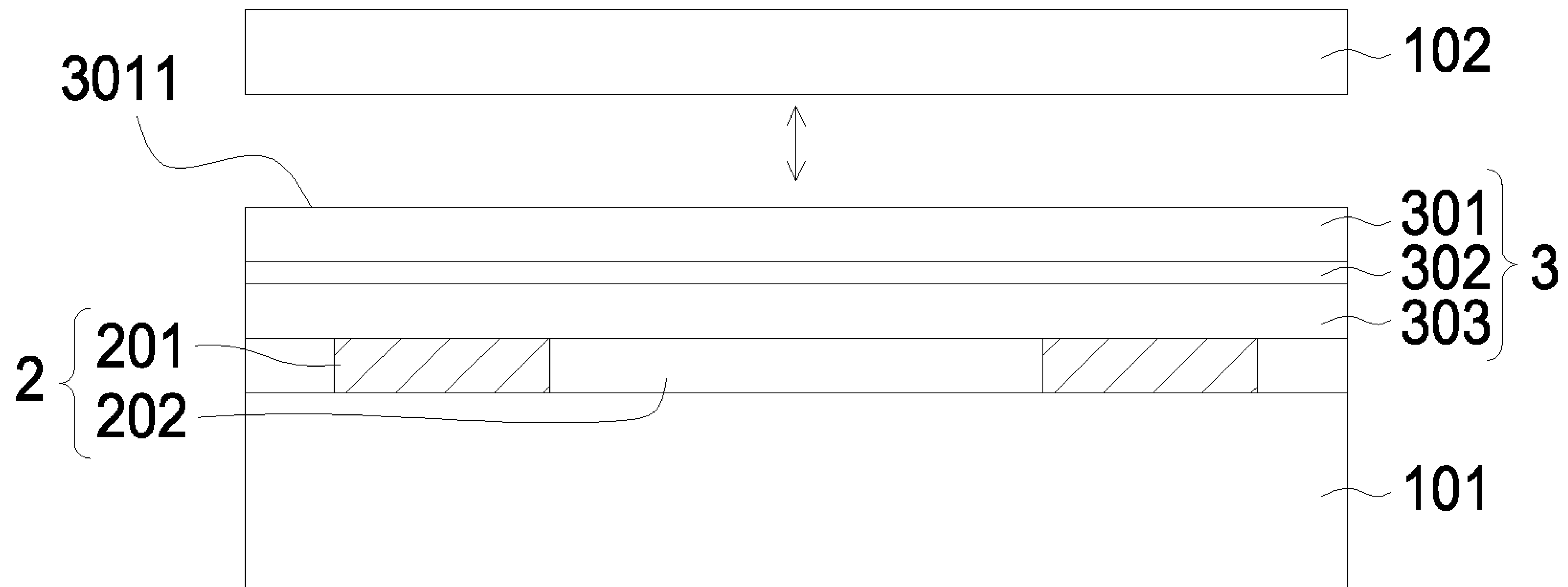



FIG. 1D

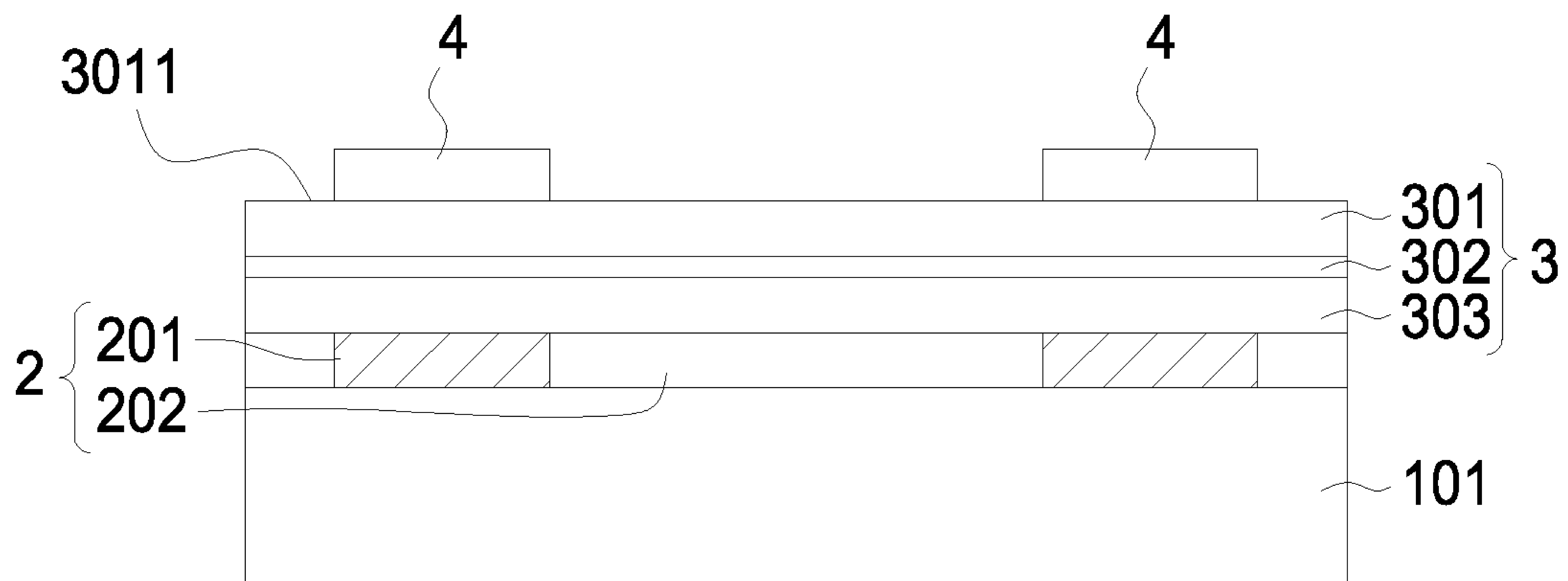



FIG. 1E

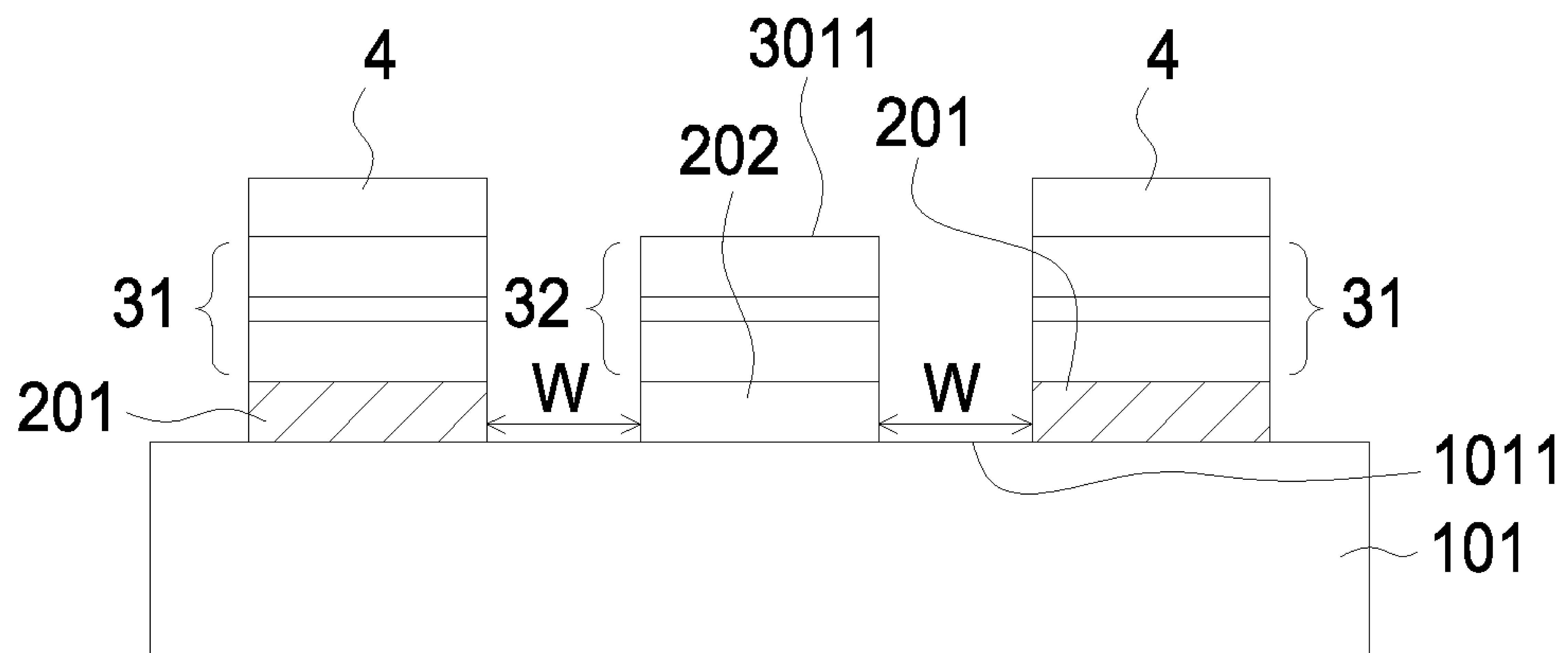



FIG. 1F

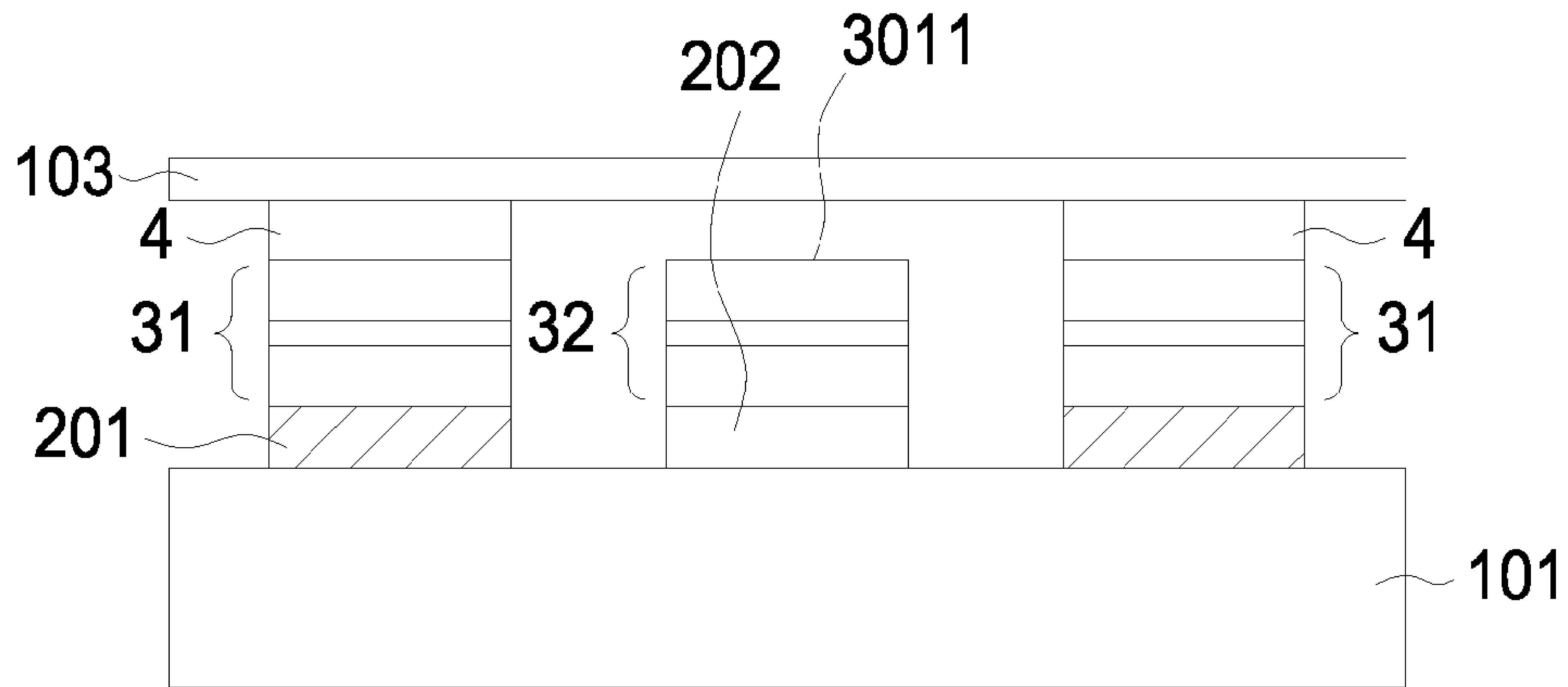



FIG. 1G

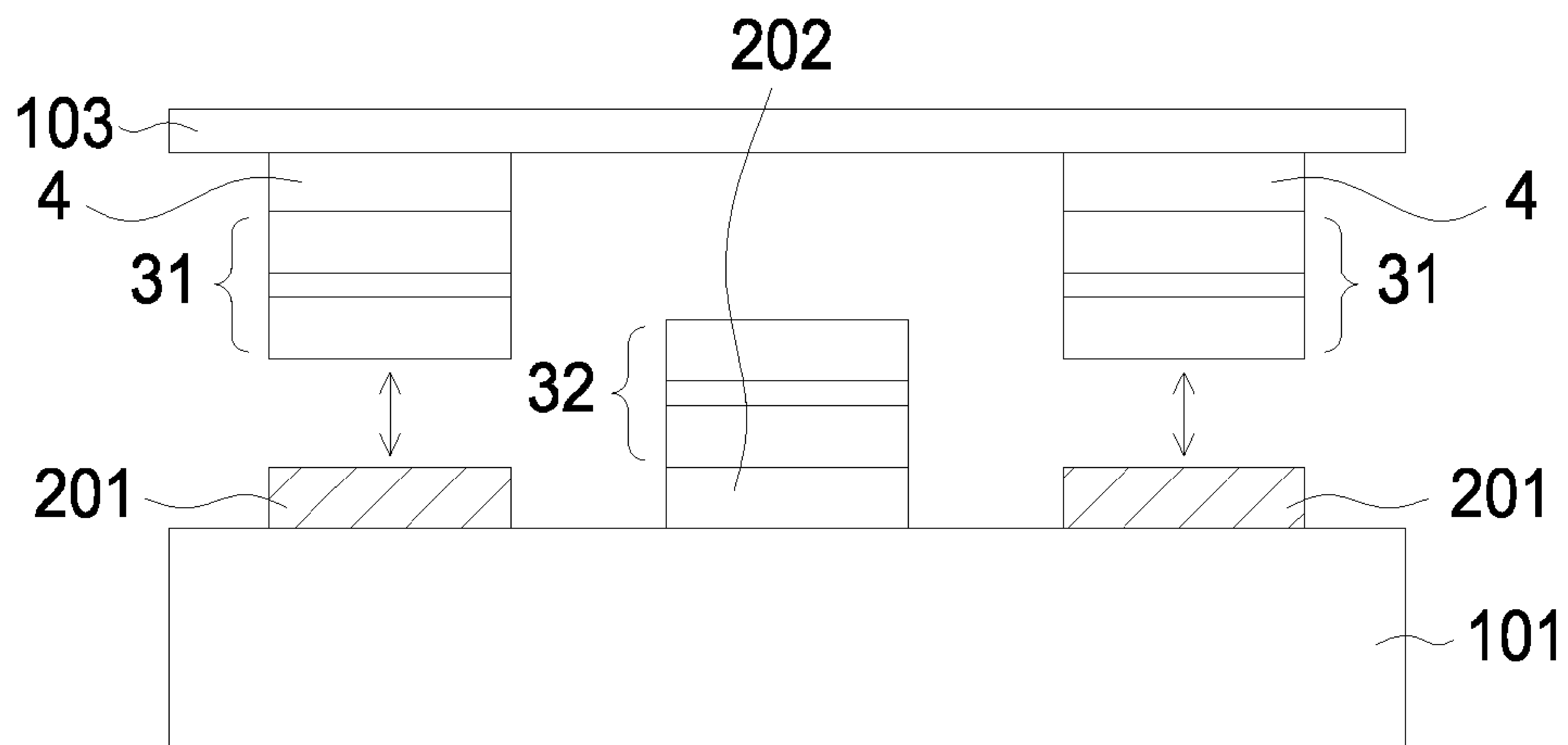



FIG. 1H

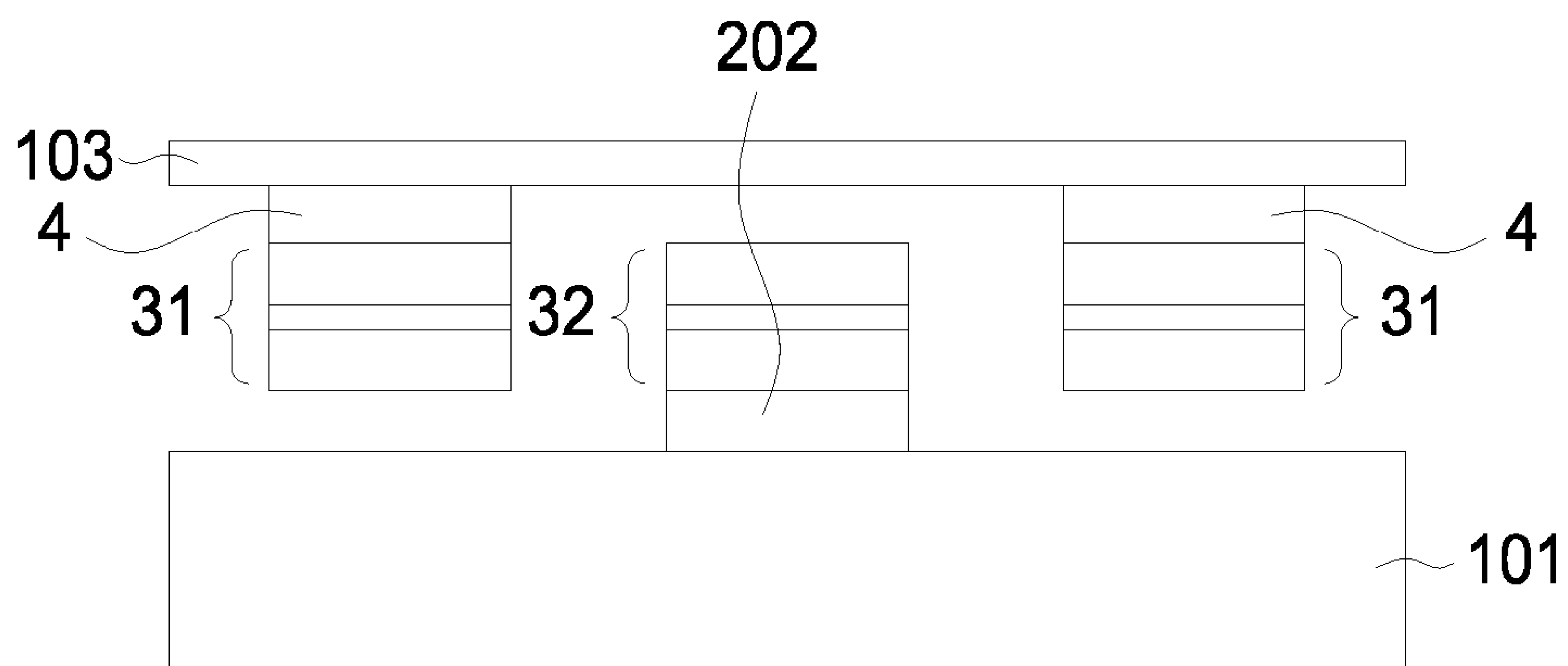



FIG. 1I

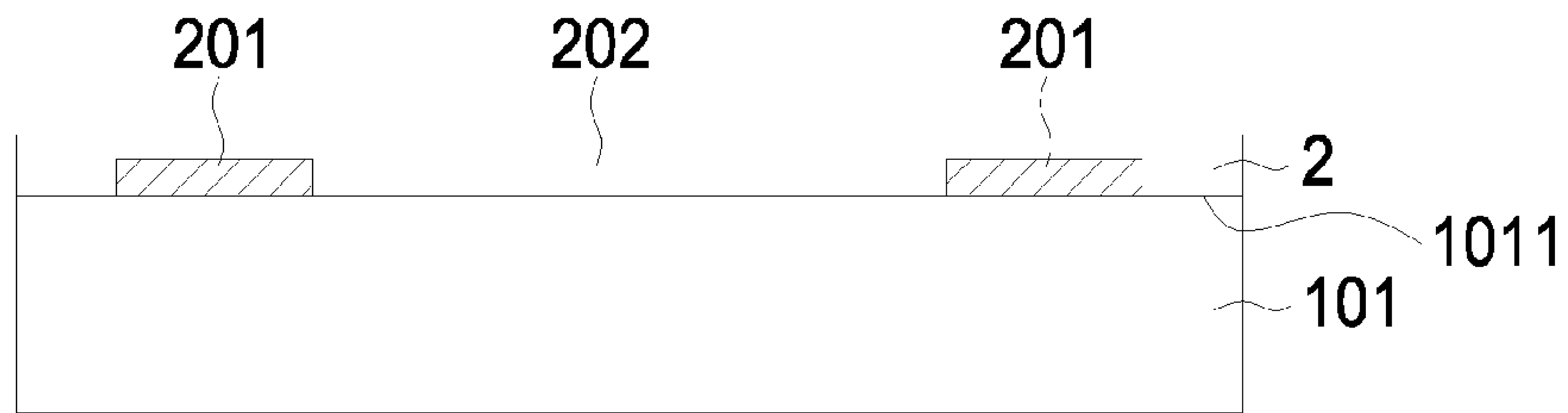



FIG. 2A

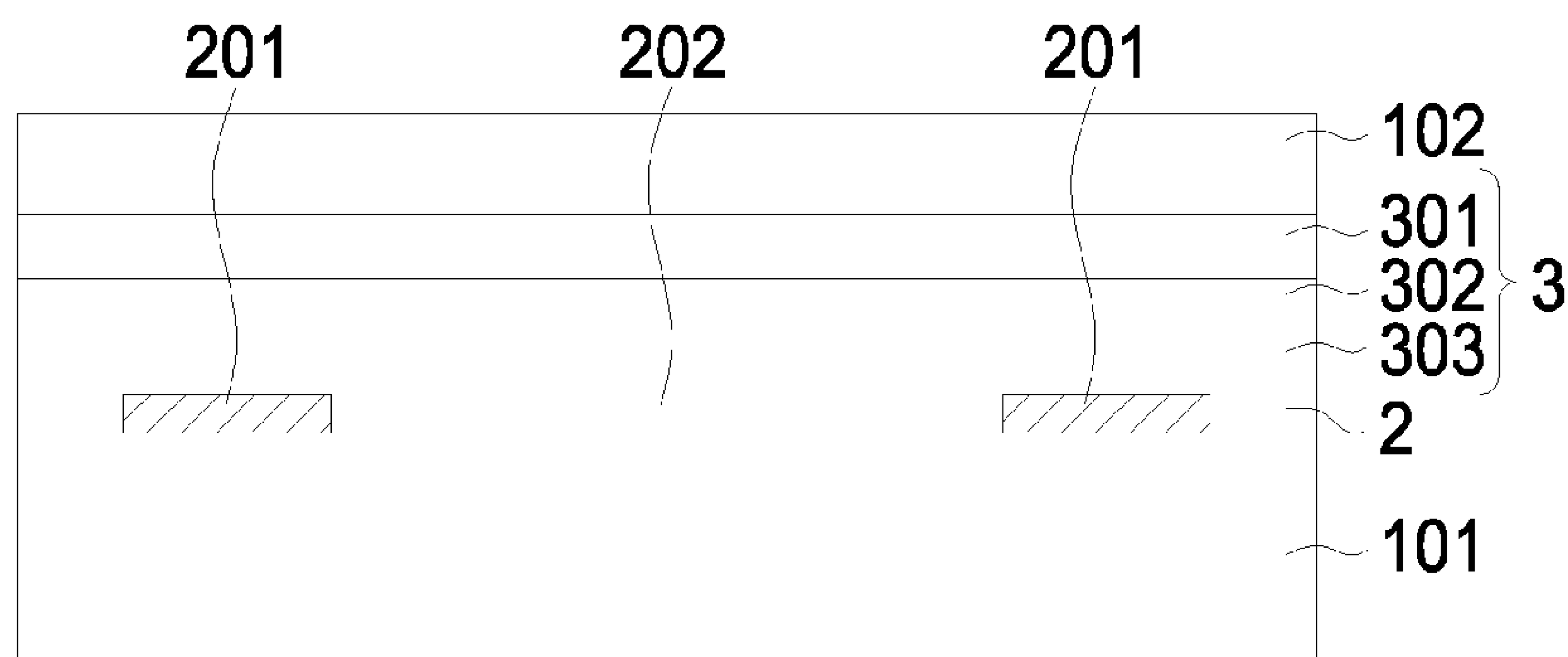



FIG. 2B

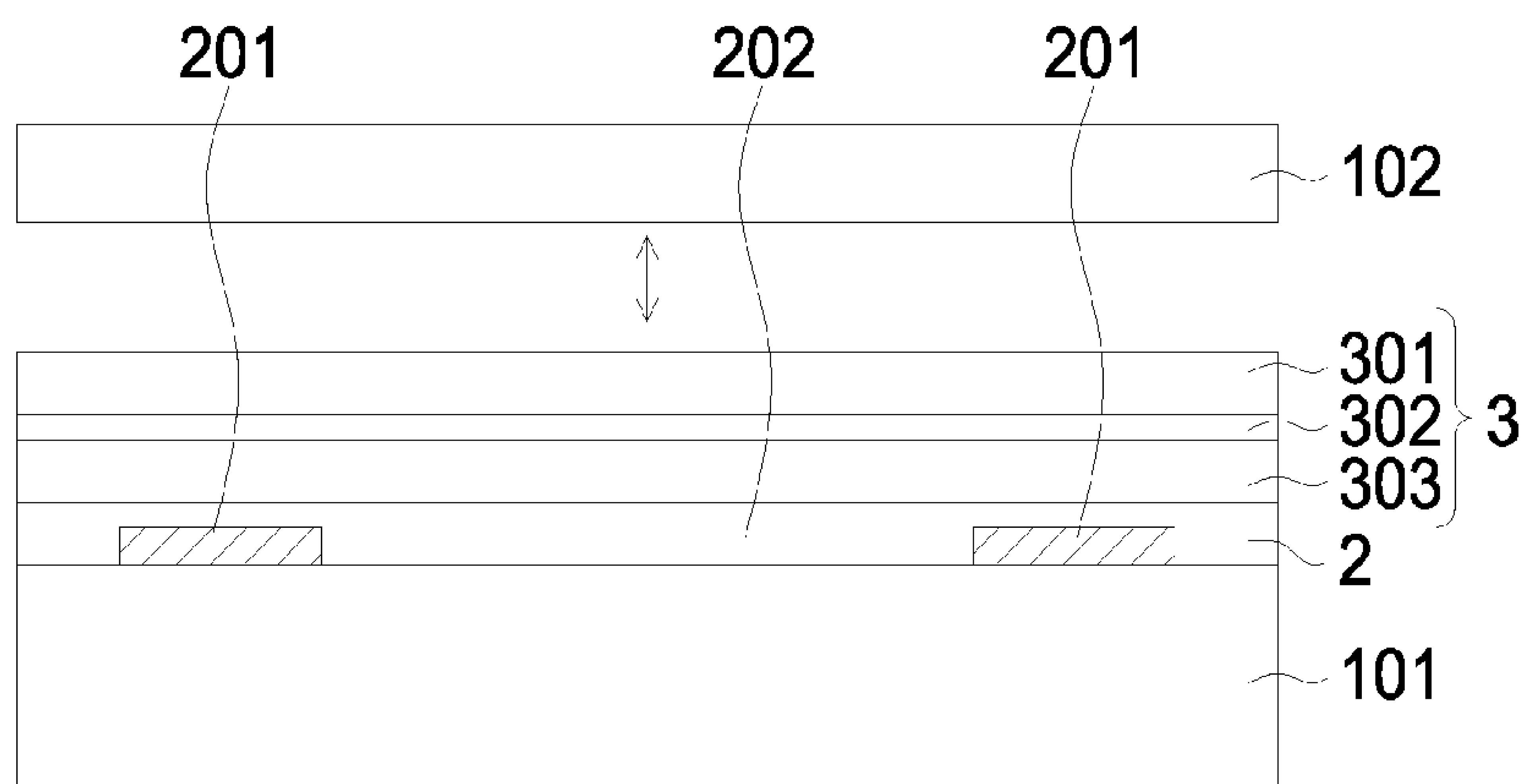



FIG. 2C

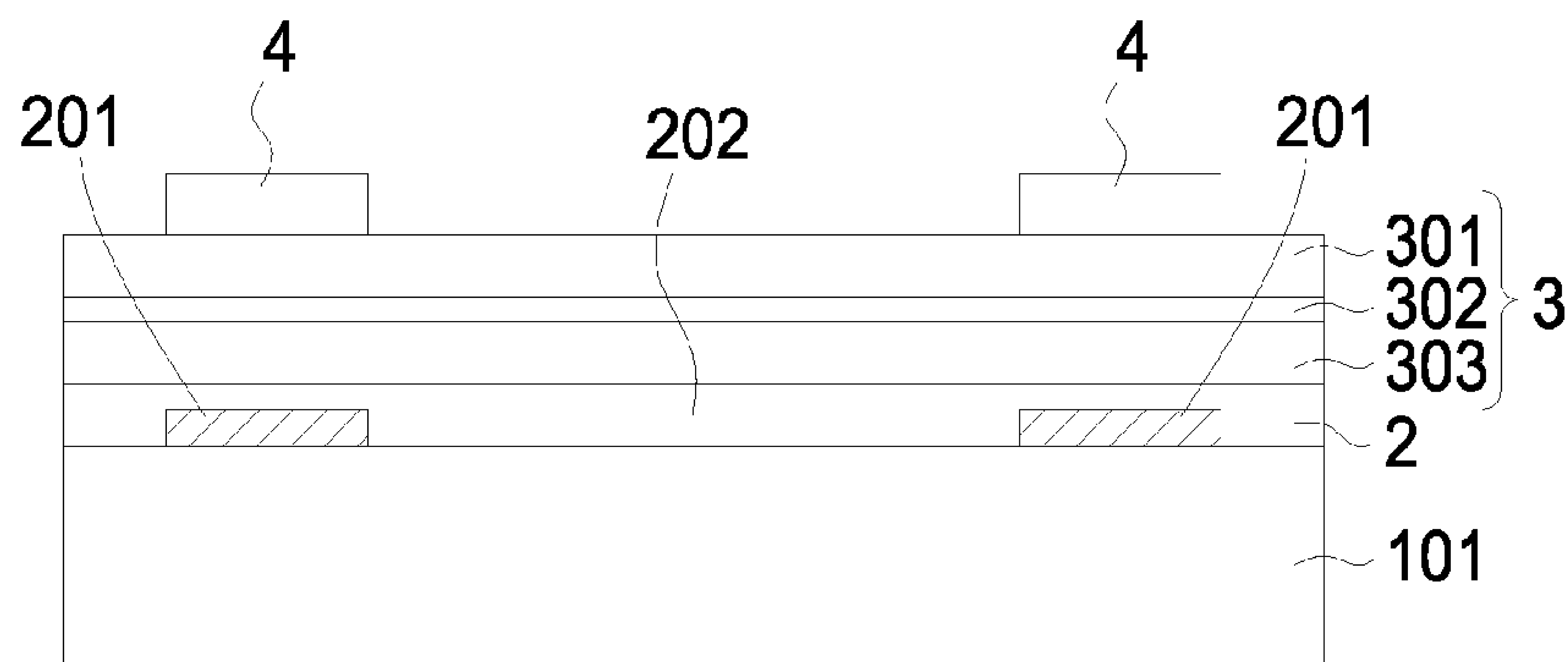



FIG. 2D

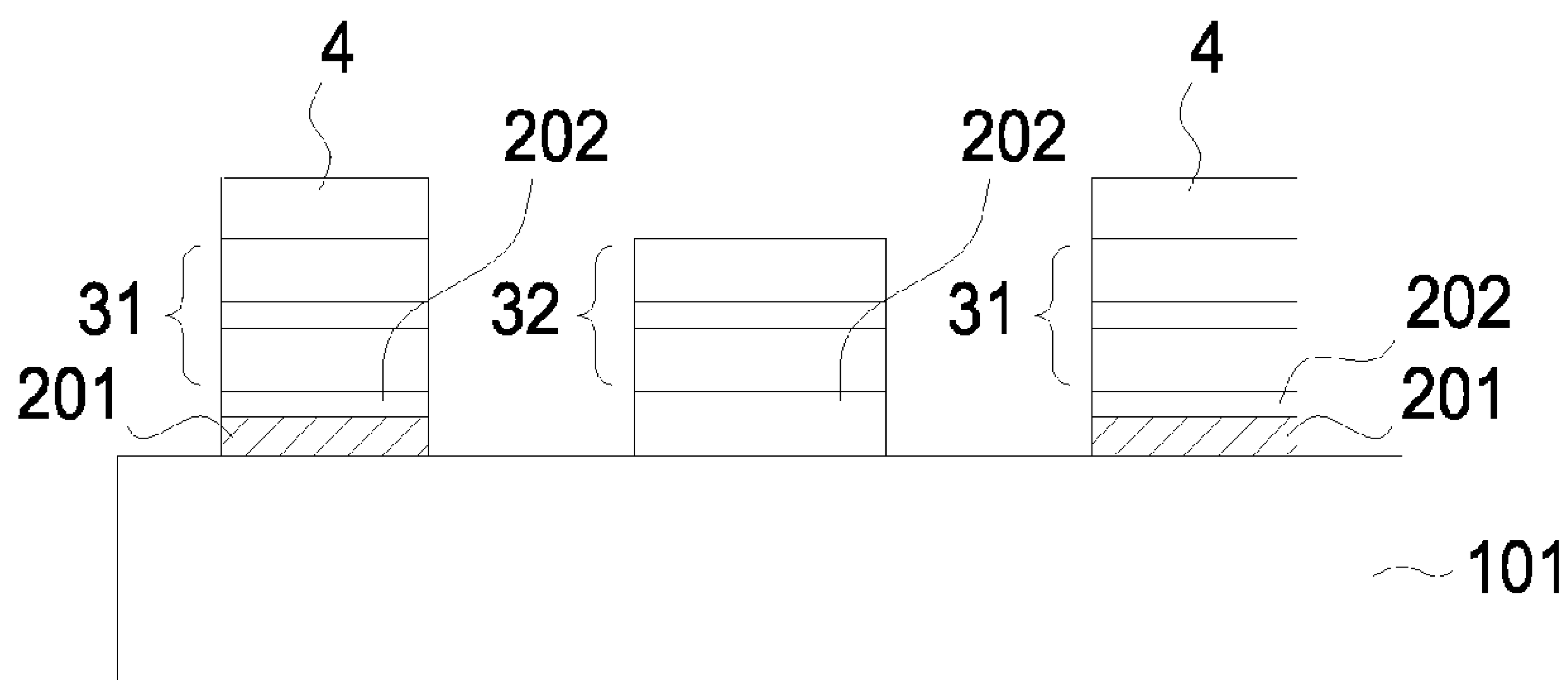



FIG. 2E

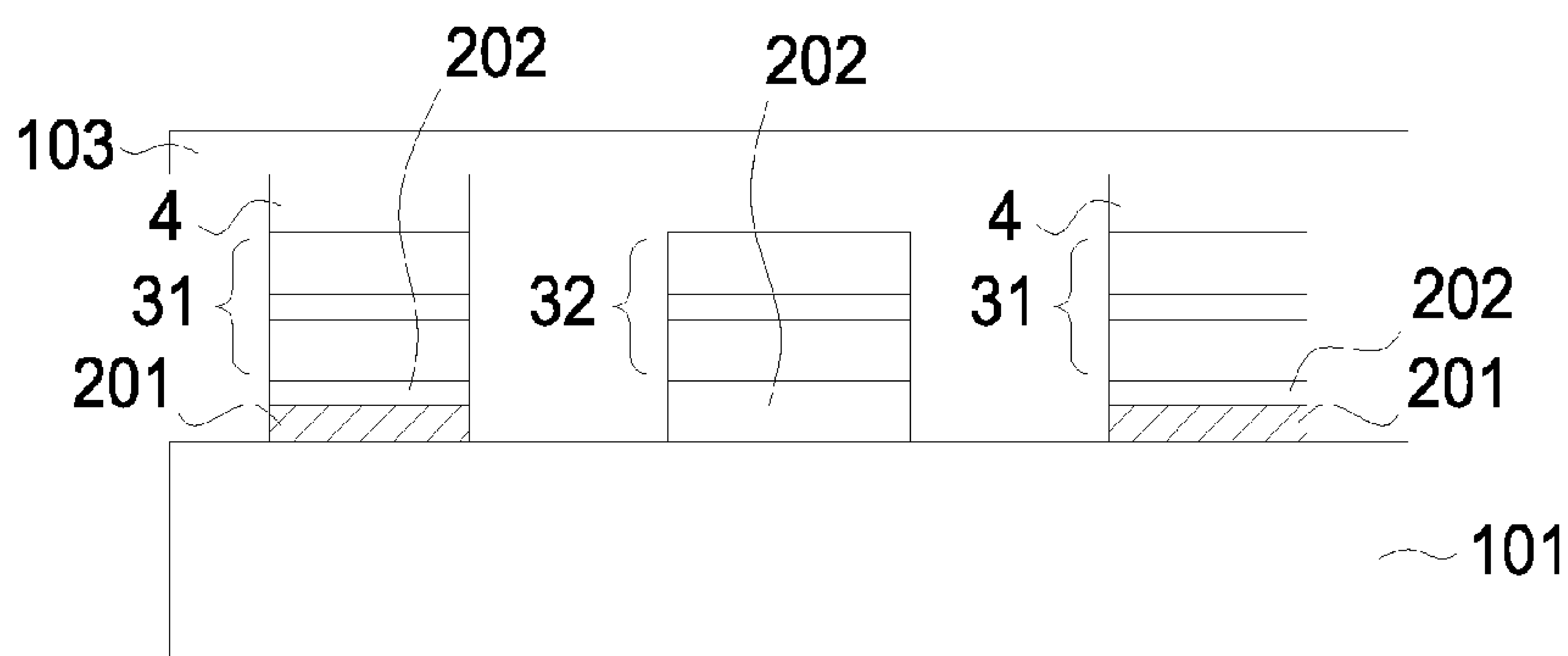



FIG. 2F

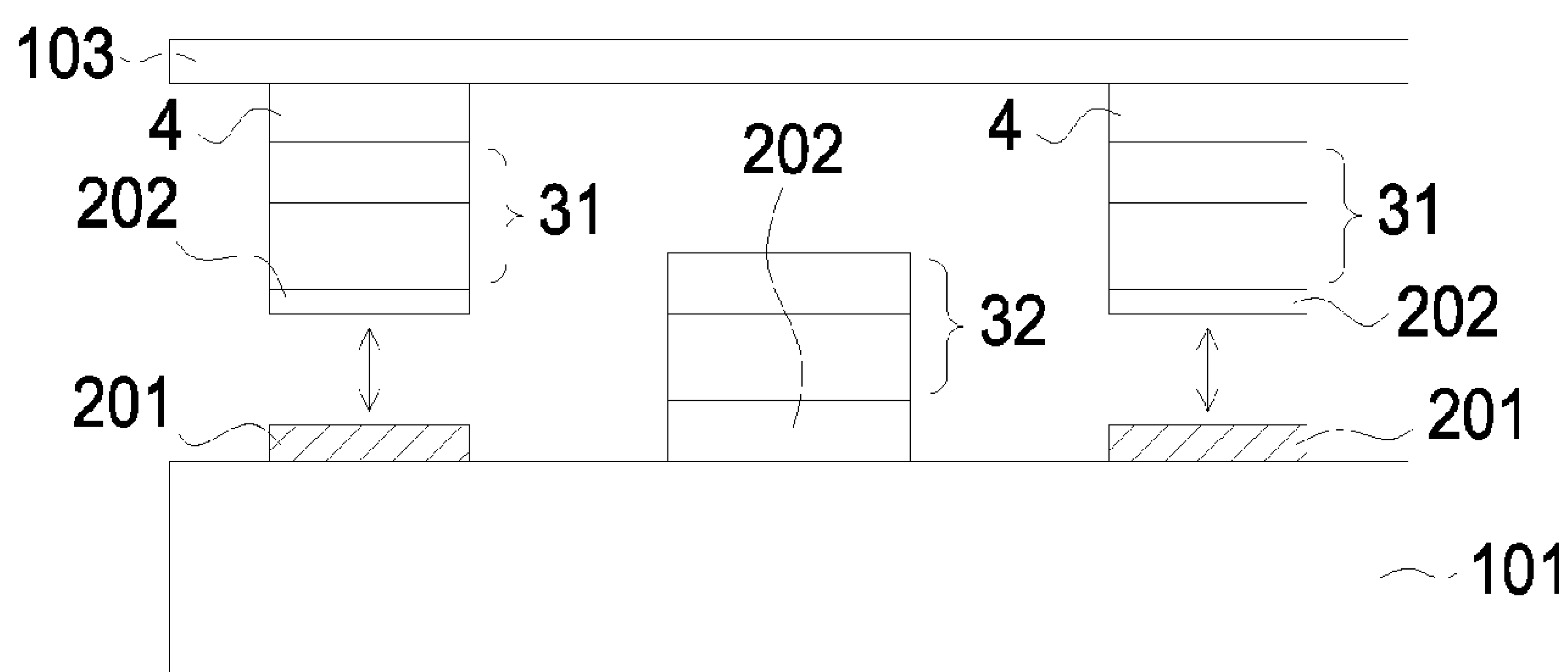



FIG. 2G

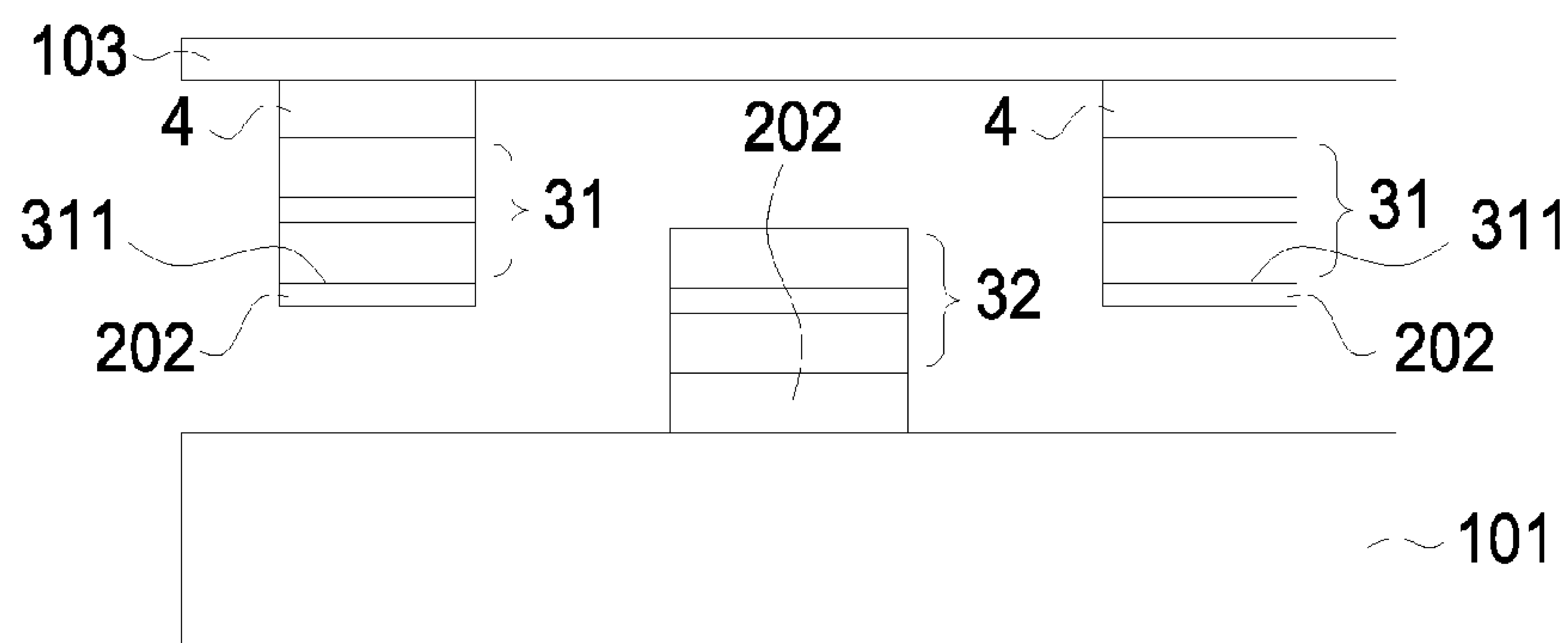



FIG. 2H

FIG. 3A

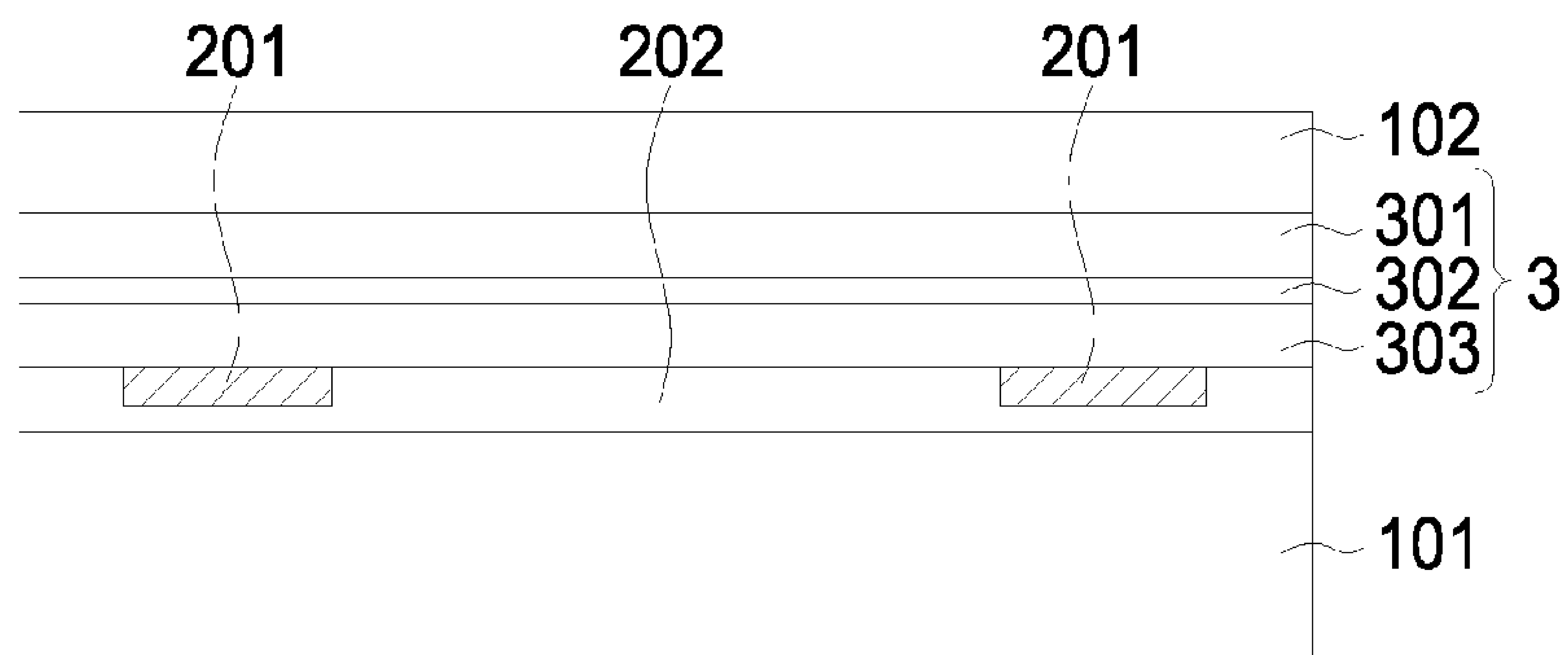


FIG. 3B

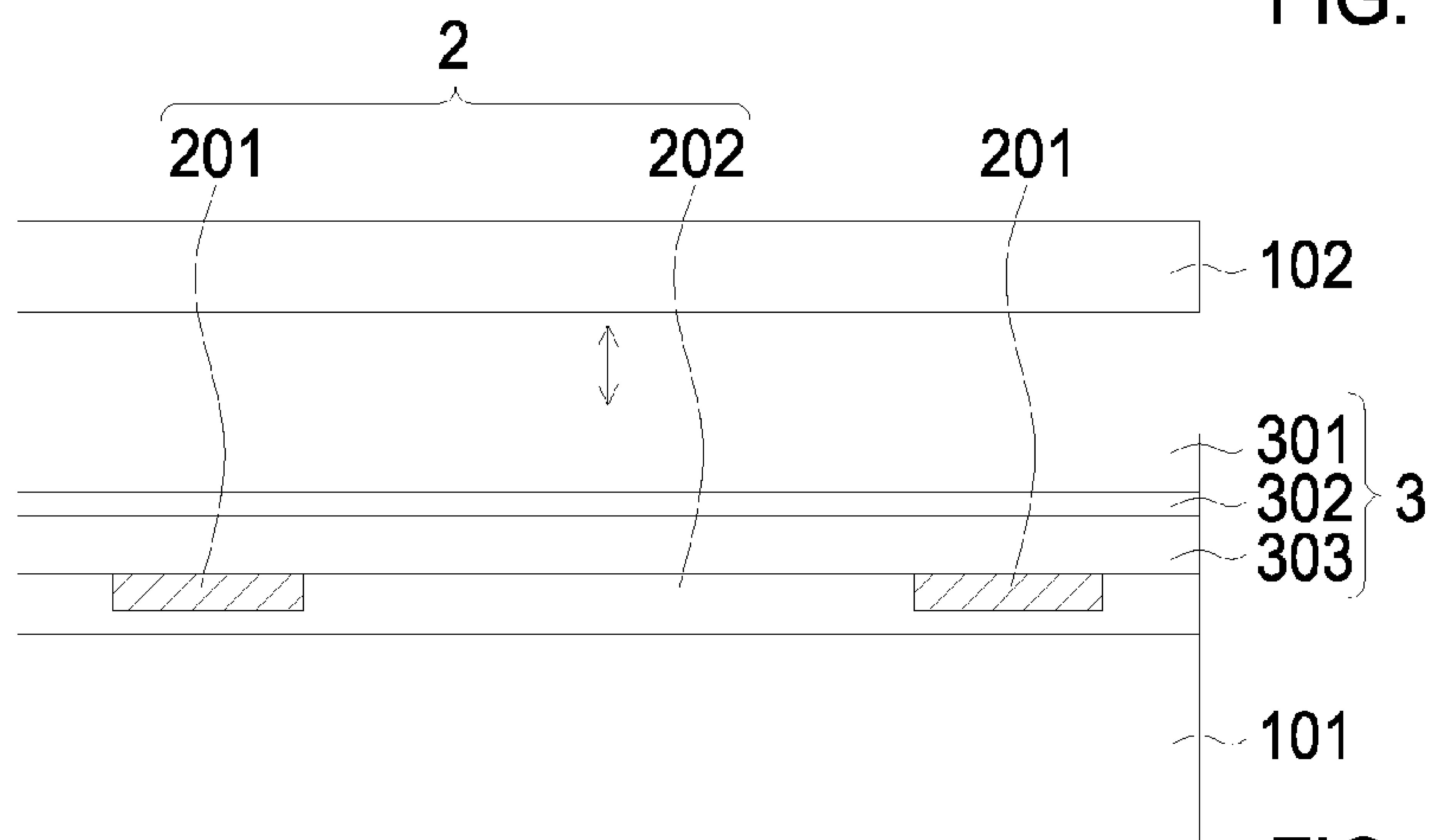
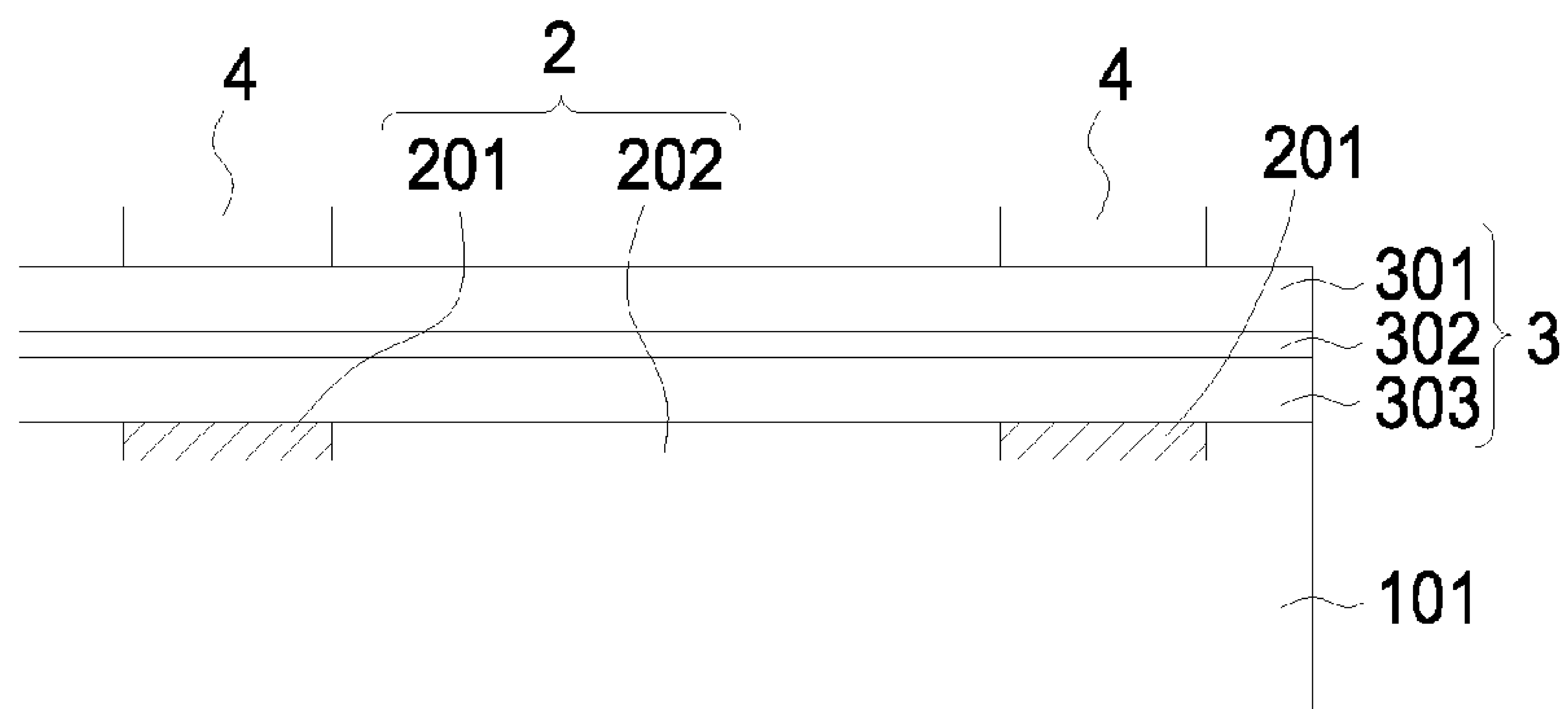


FIG. 3C



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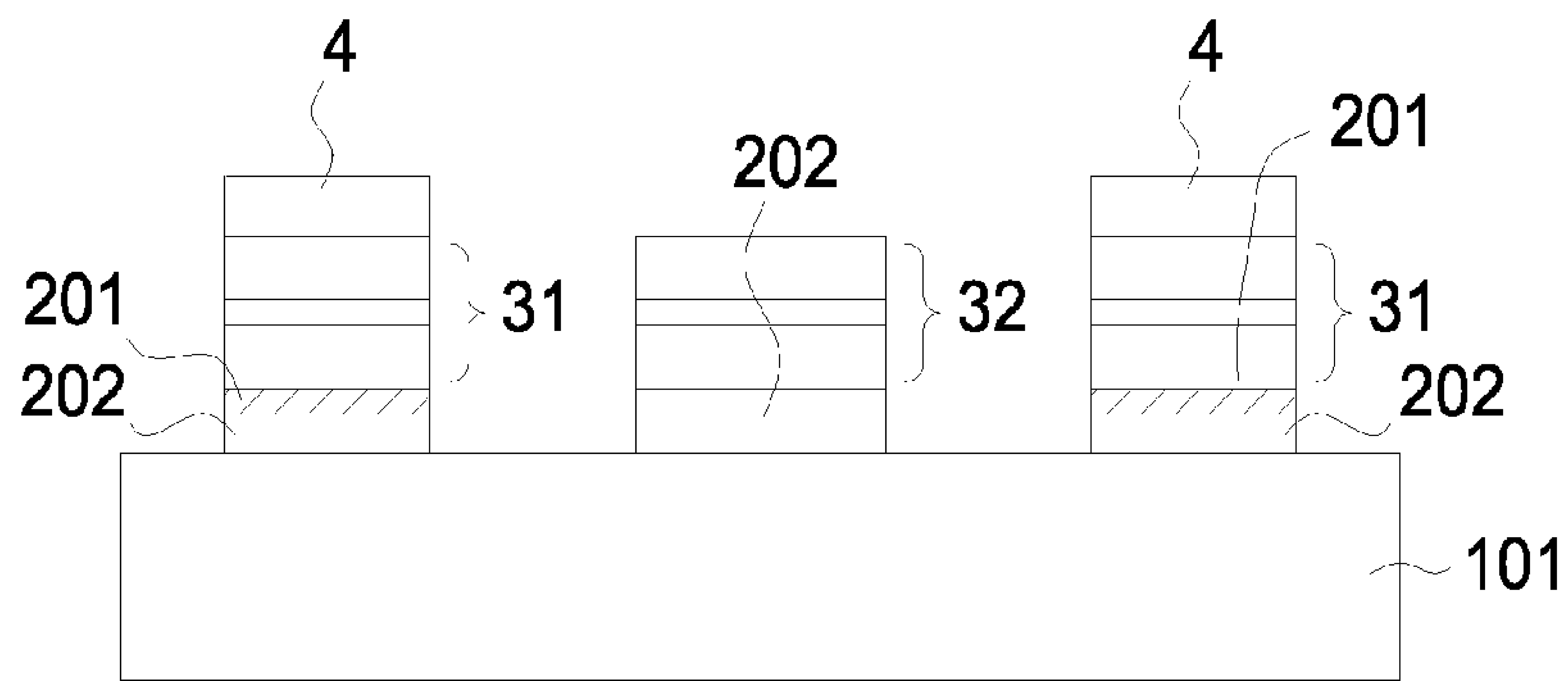


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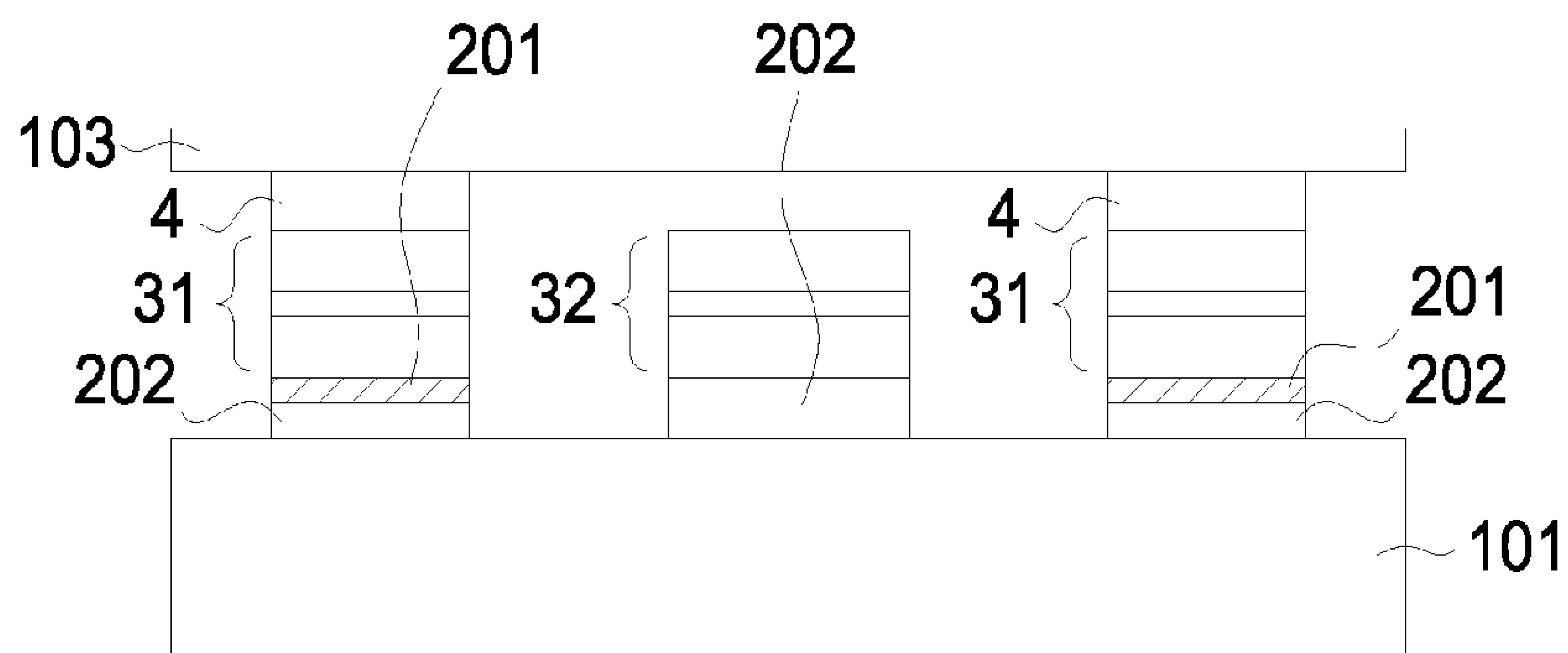


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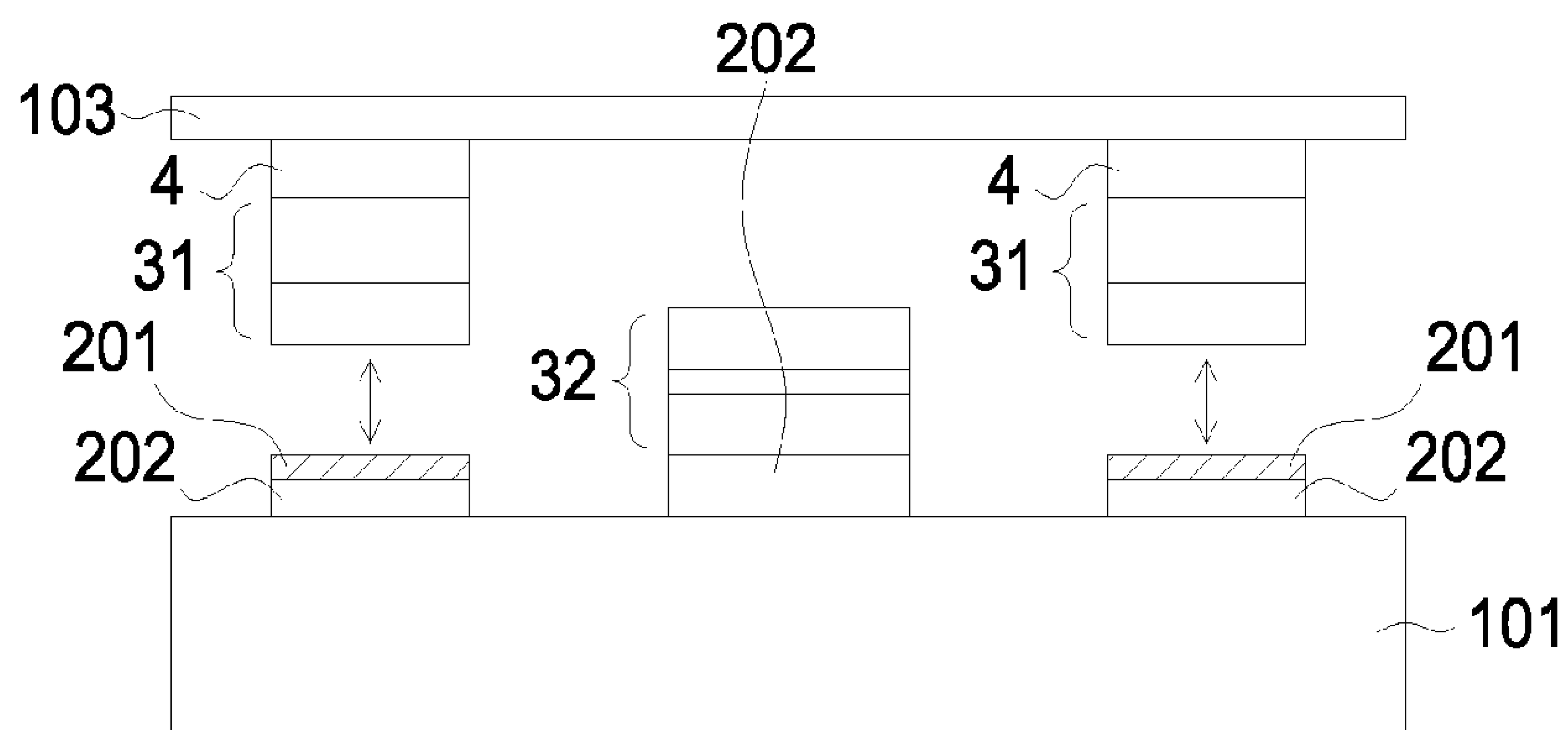


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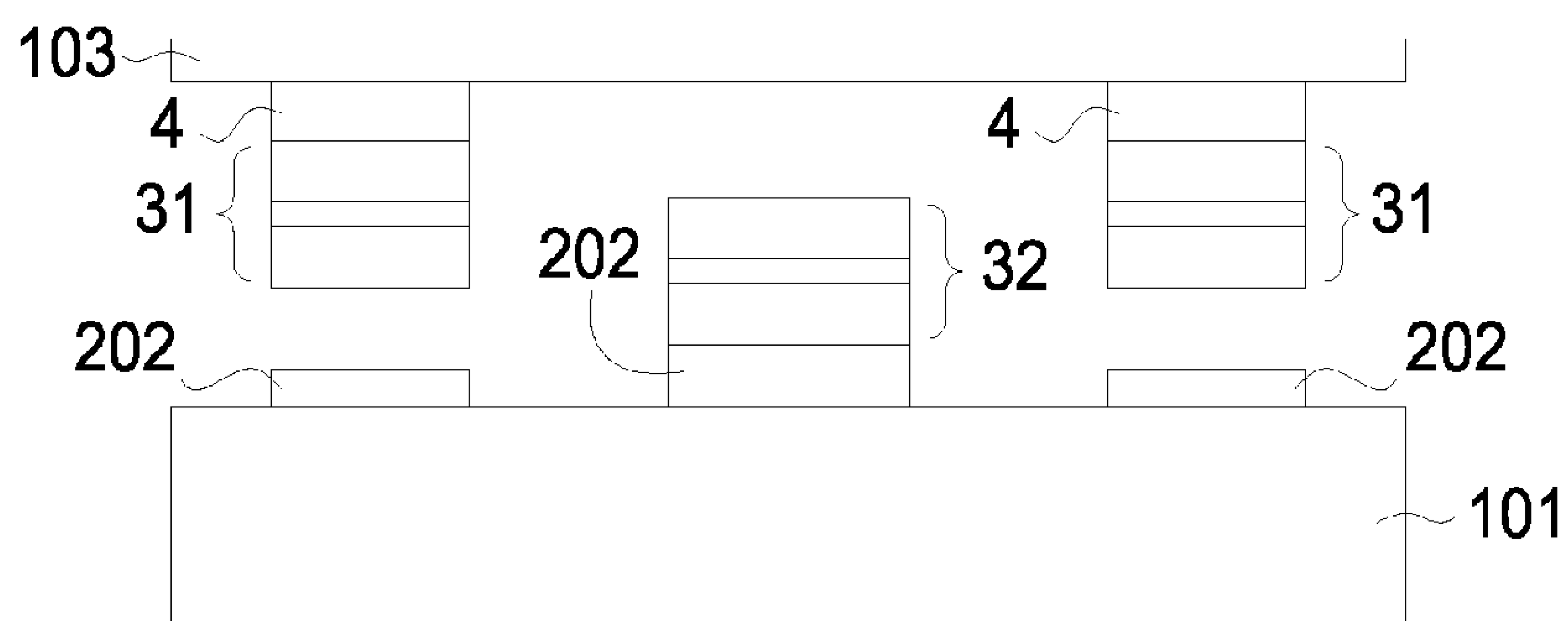



FIG. 3H

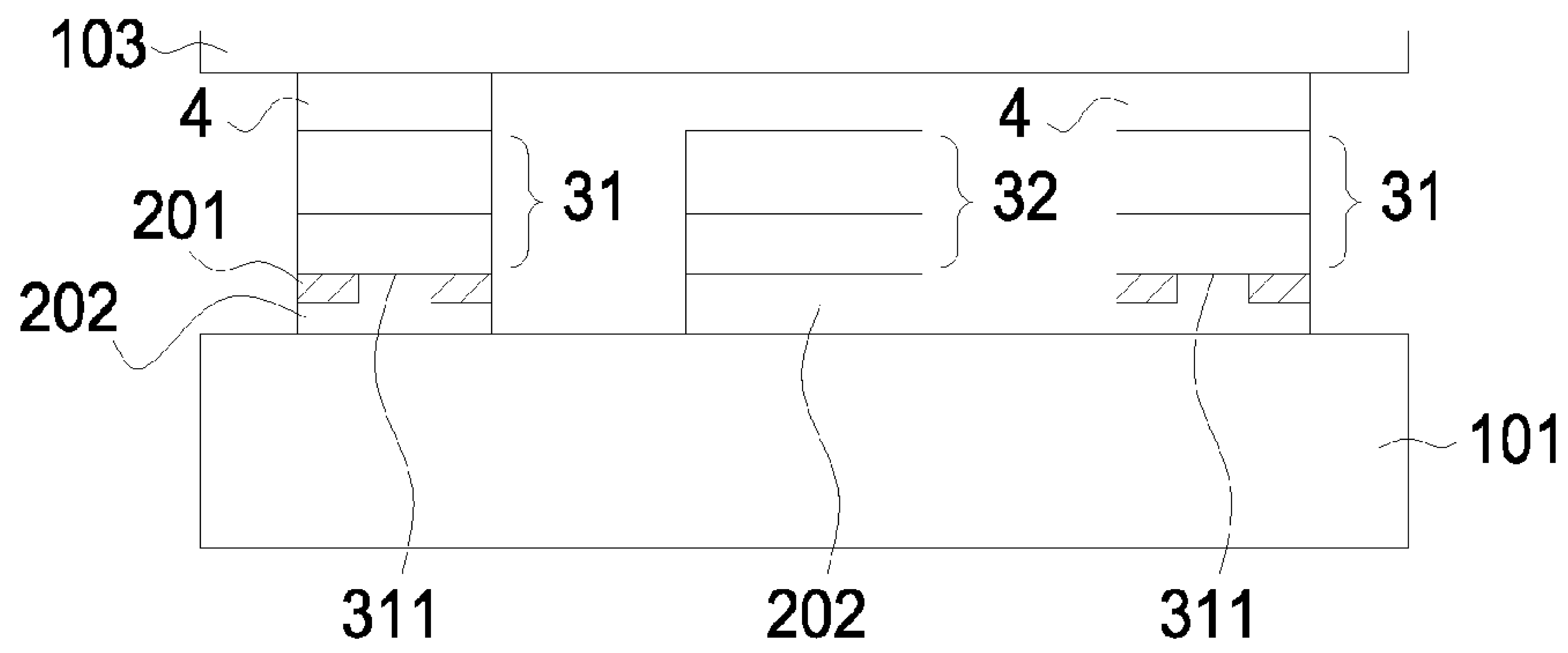



FIG. 4A

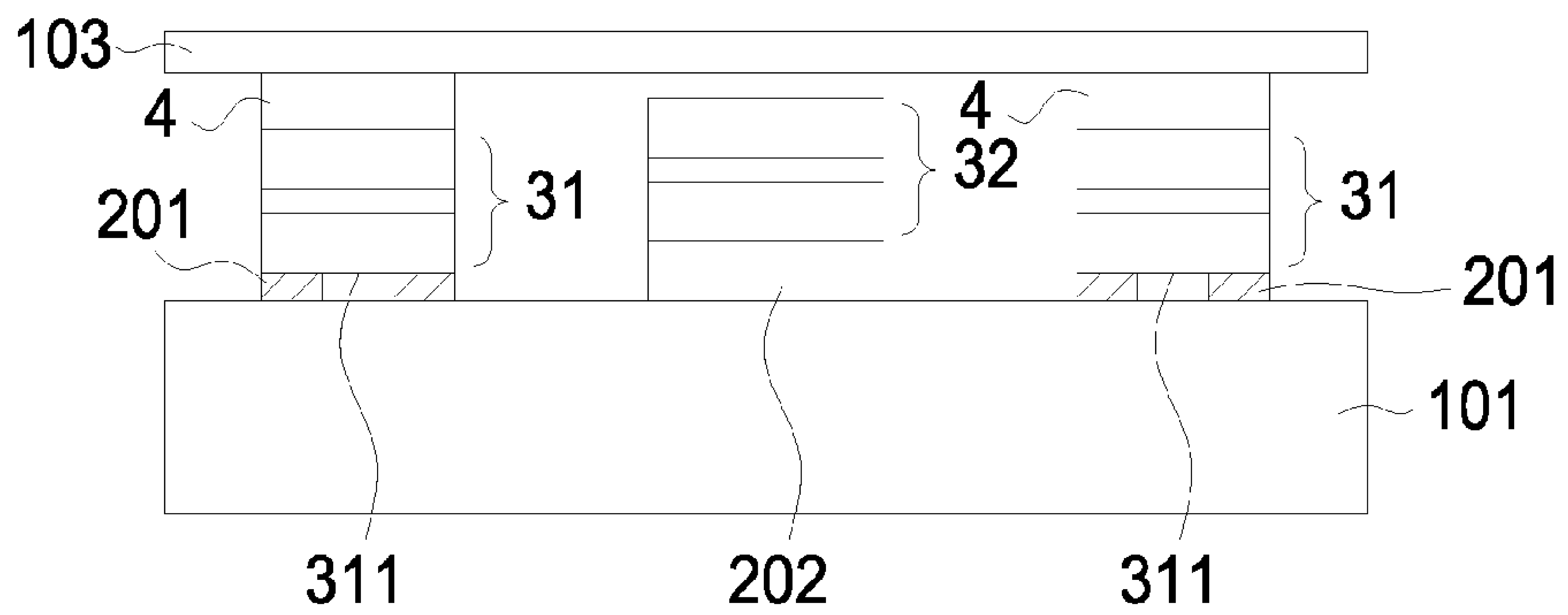



FIG. 4B

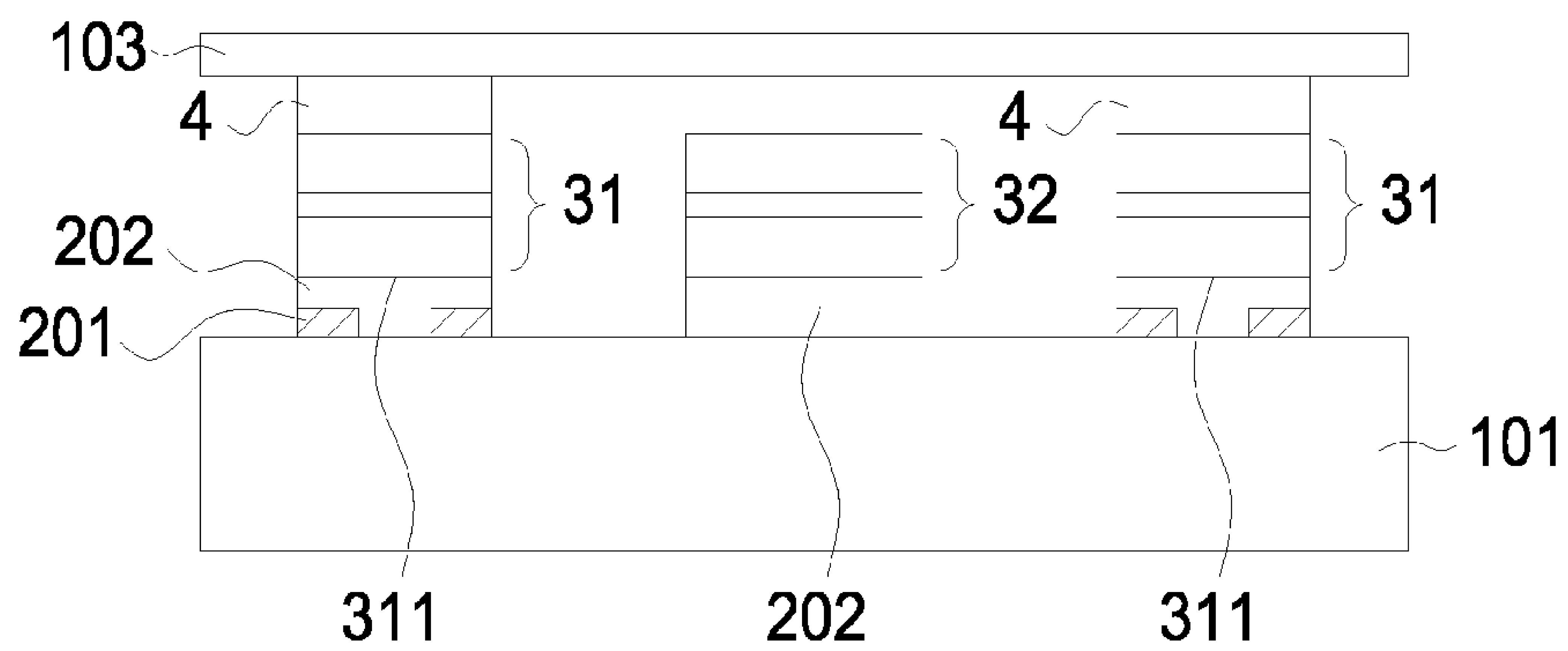



FIG. 4C

FIG. 5A

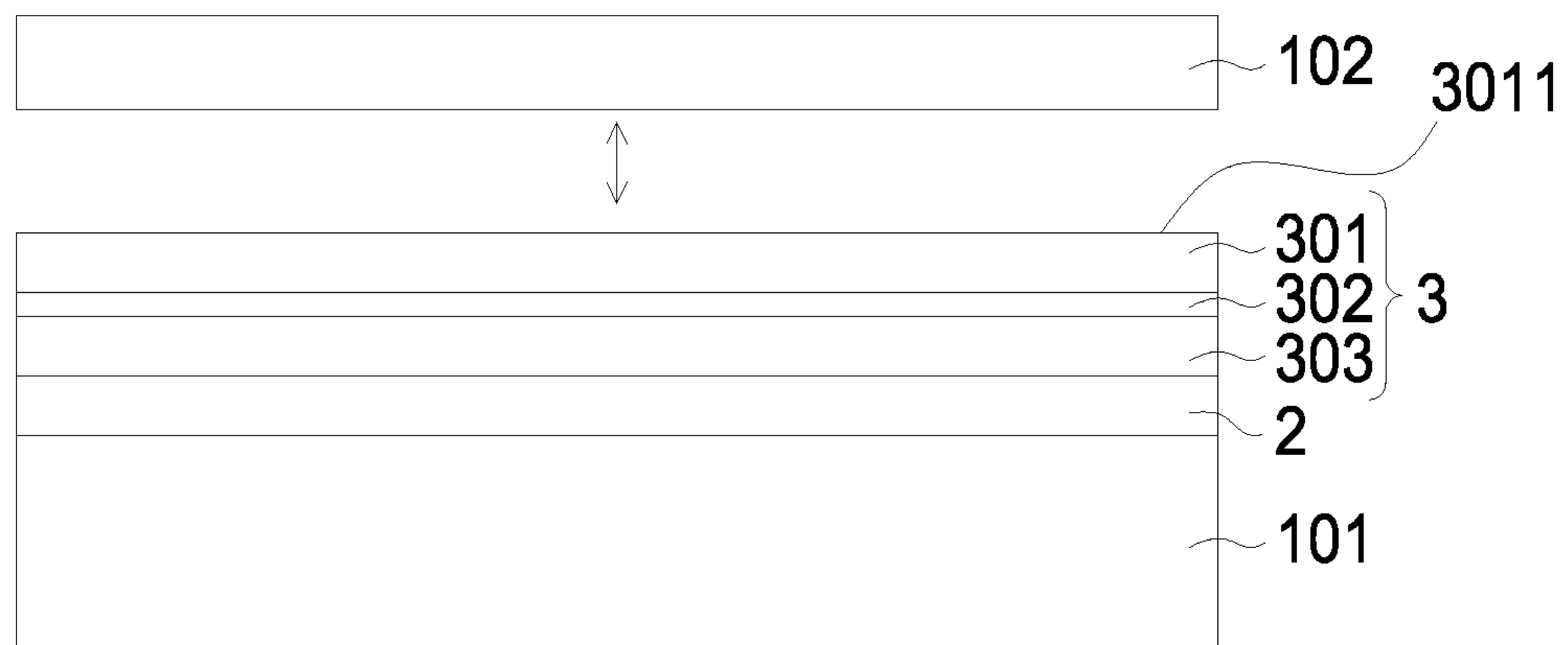



FIG. 5B

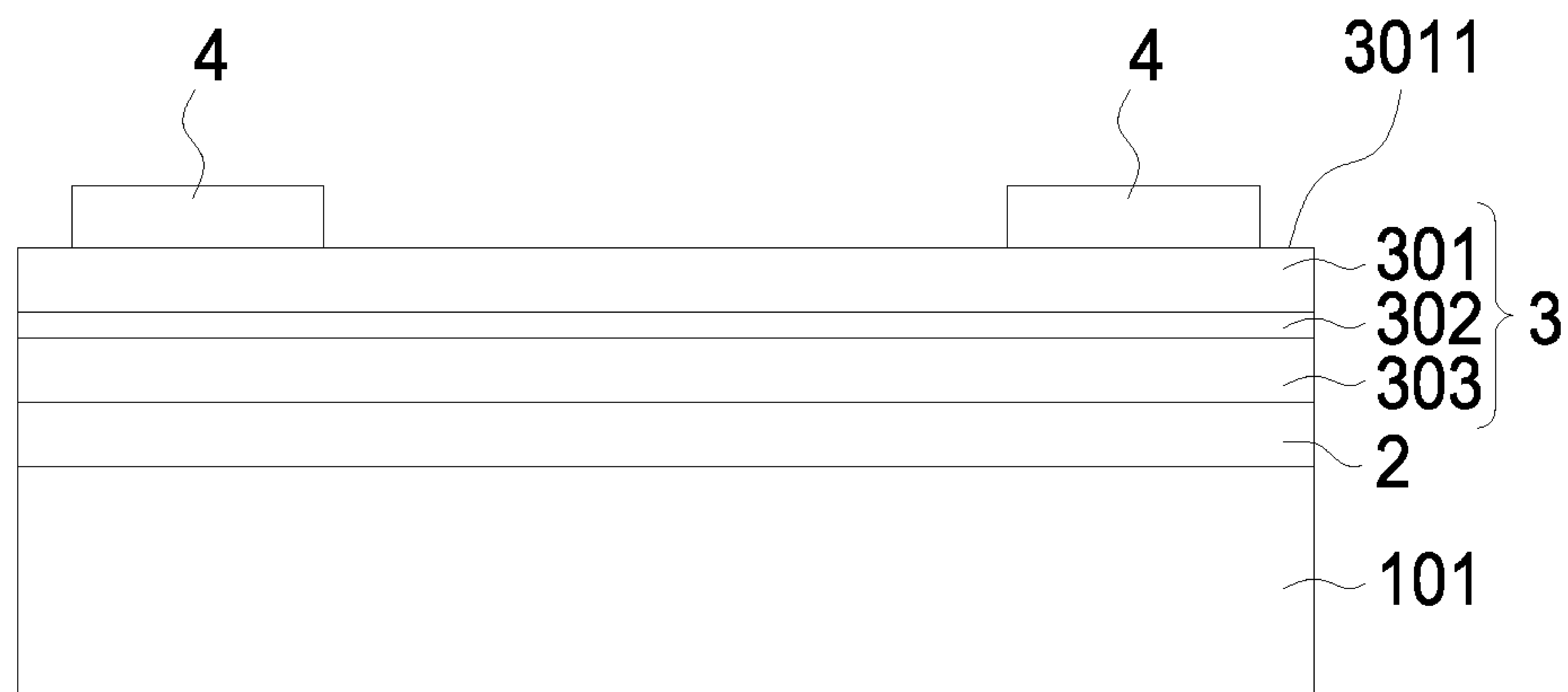
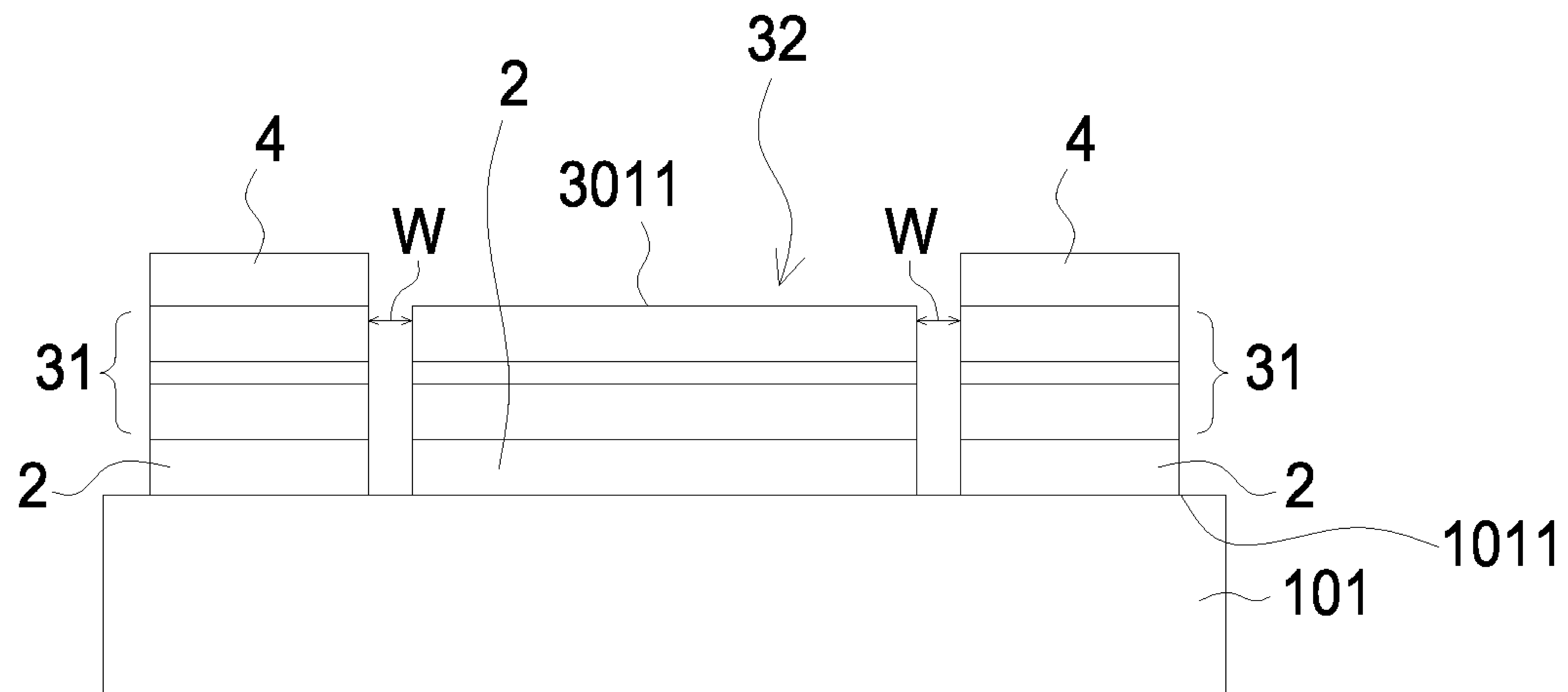



FIG. 5C

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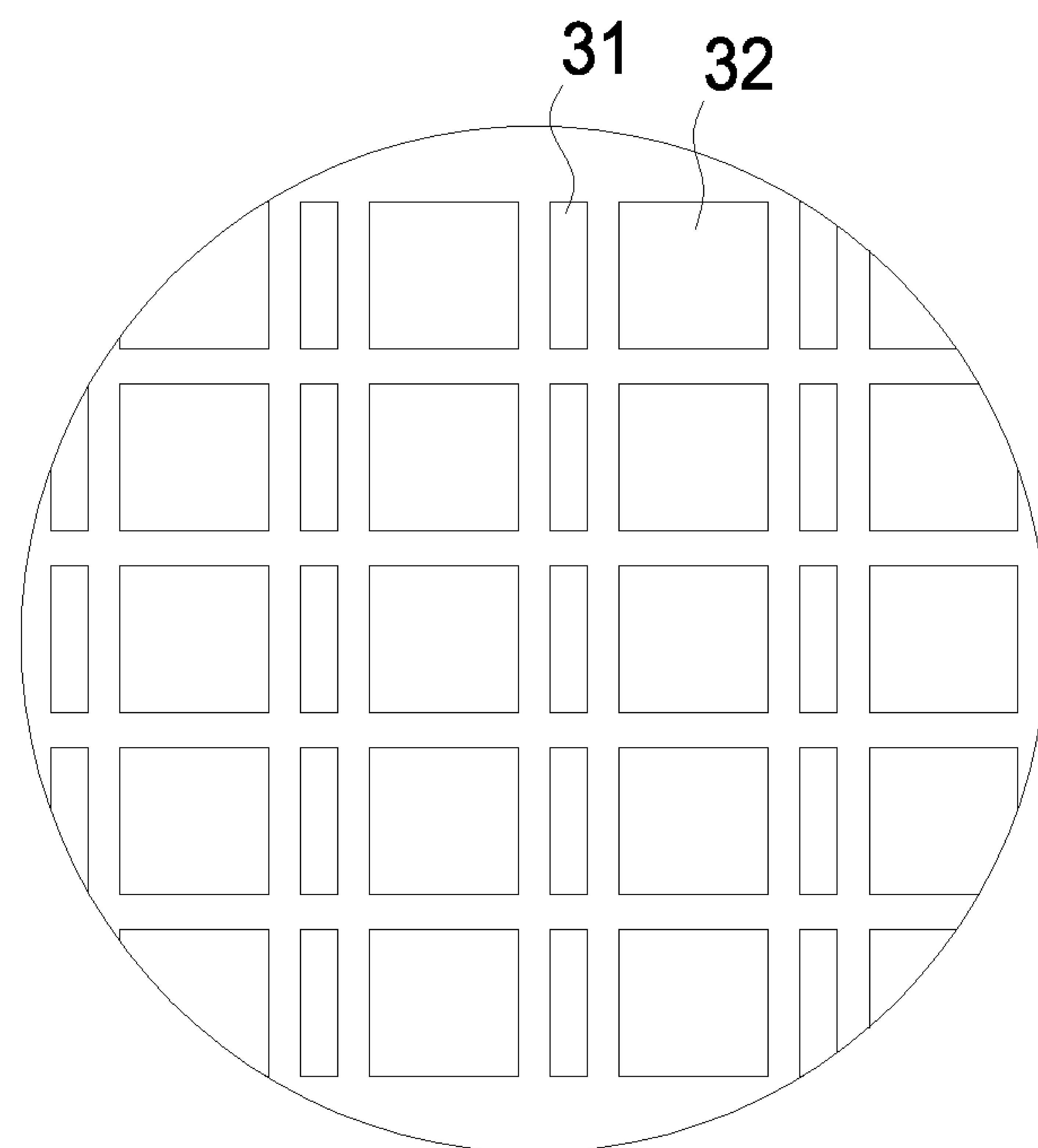
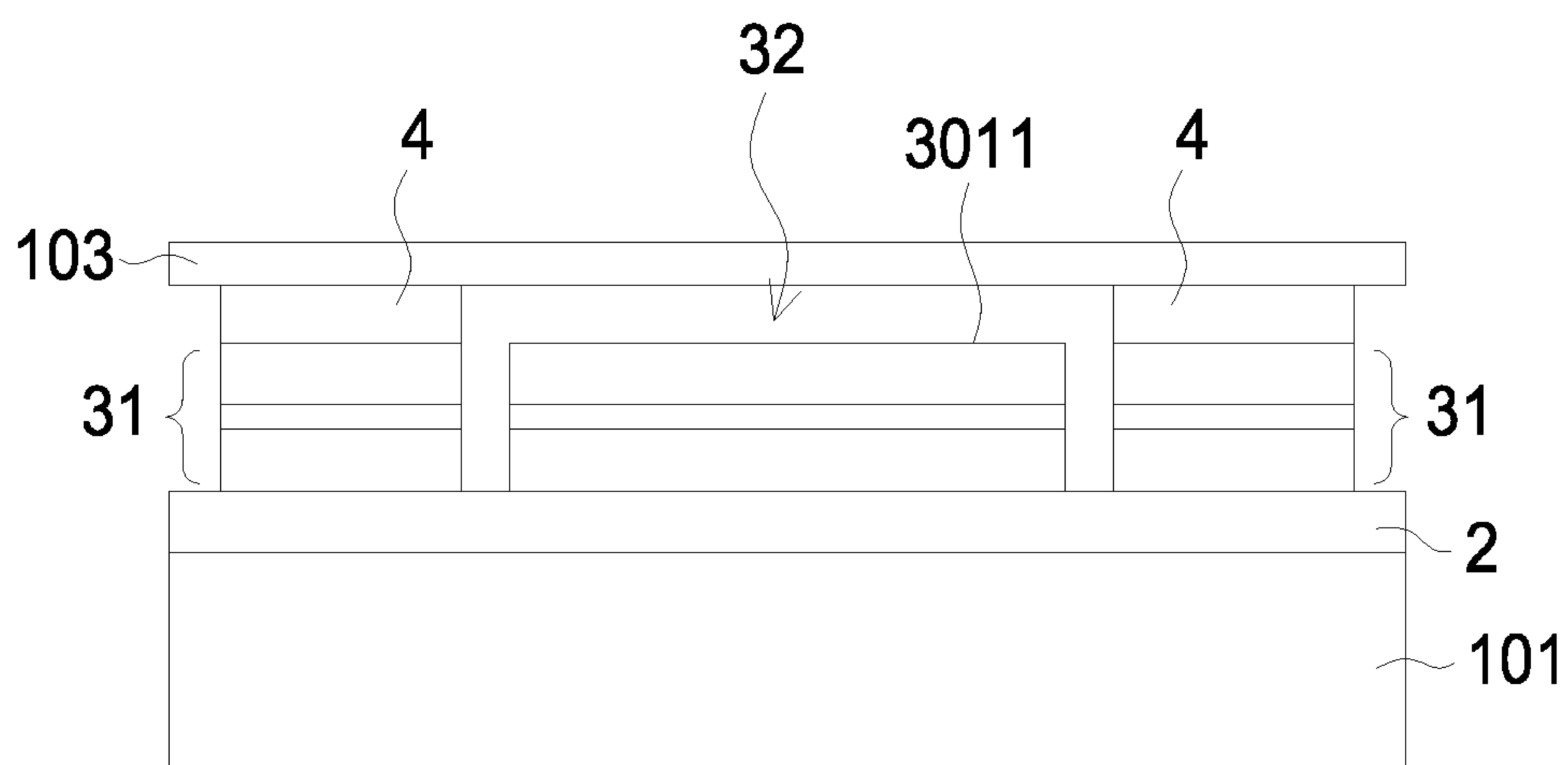



FIG. 5E

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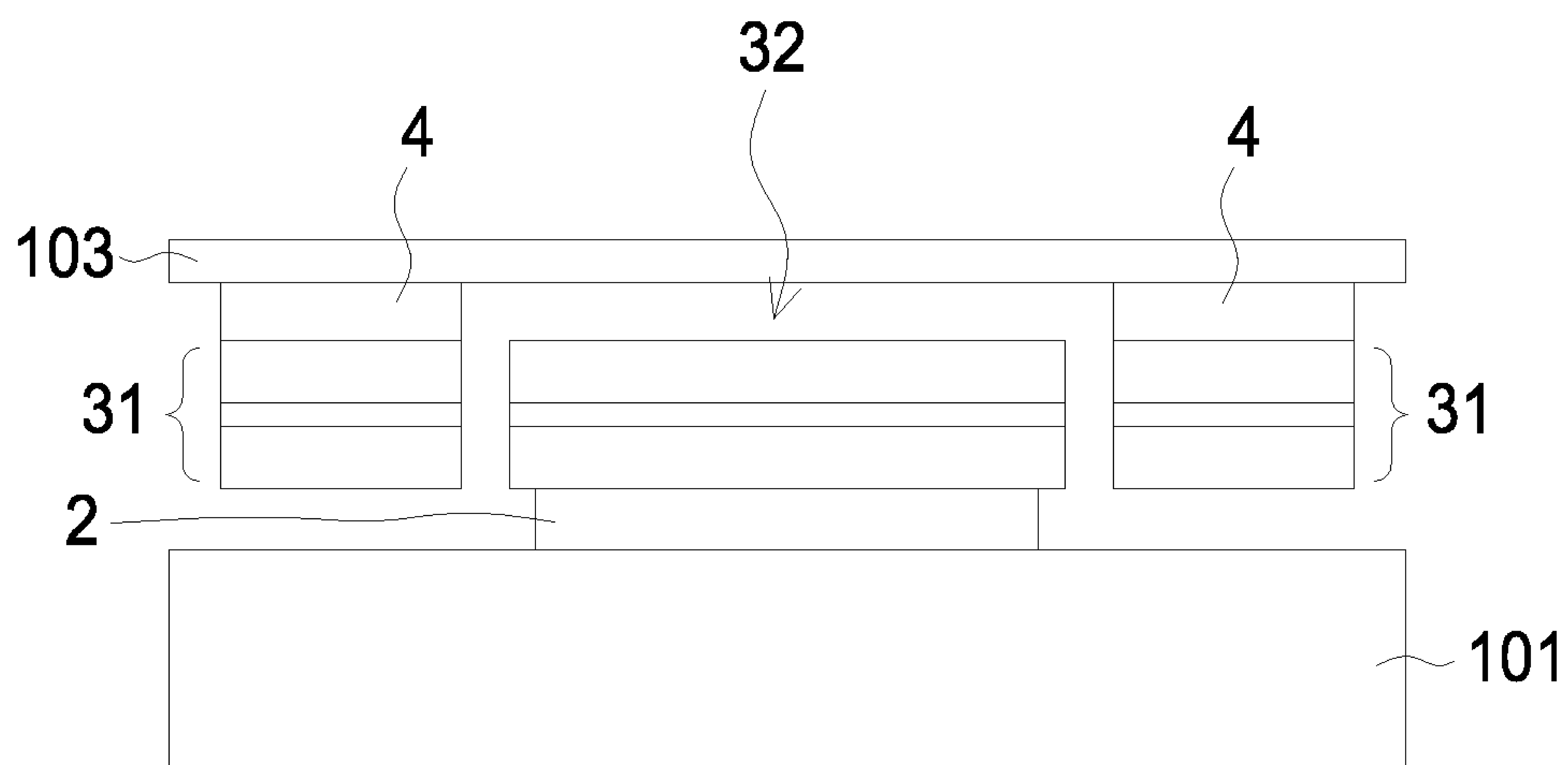



FIG. 5G

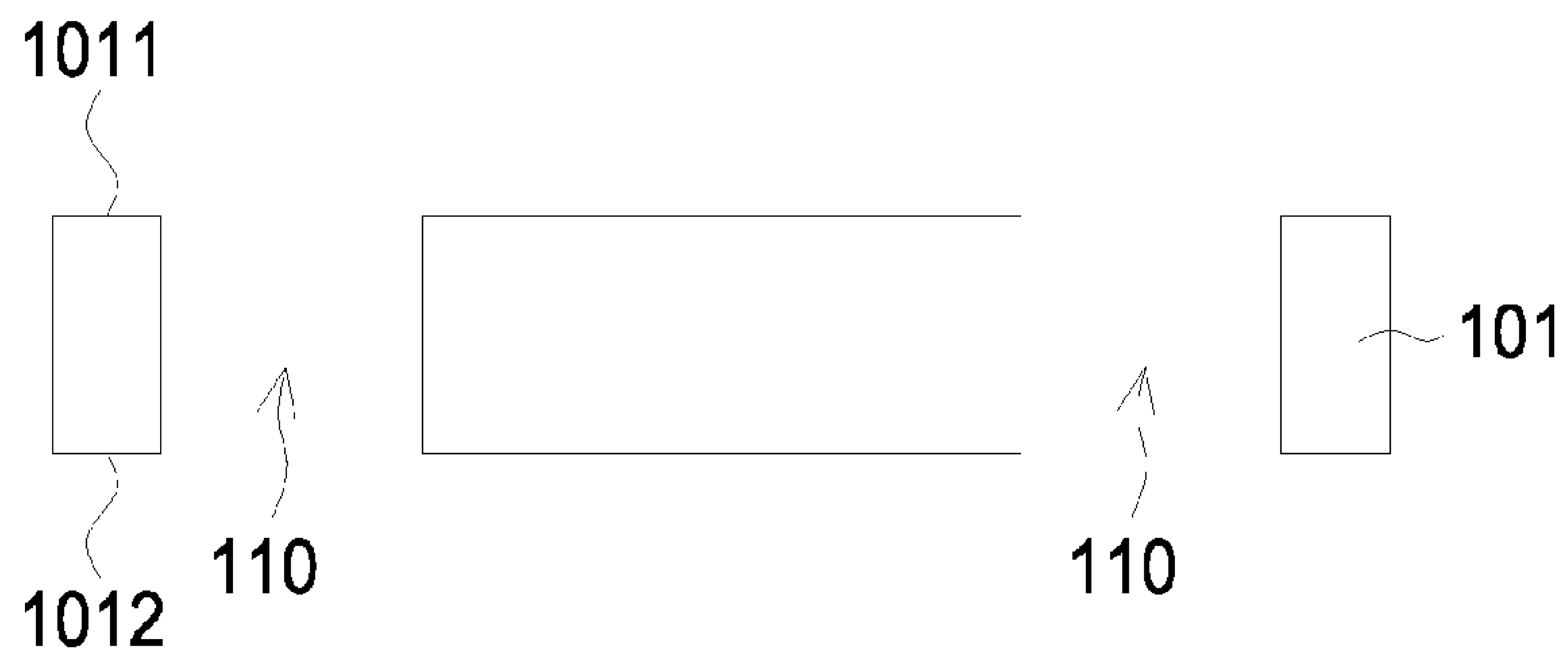



FIG. 6A

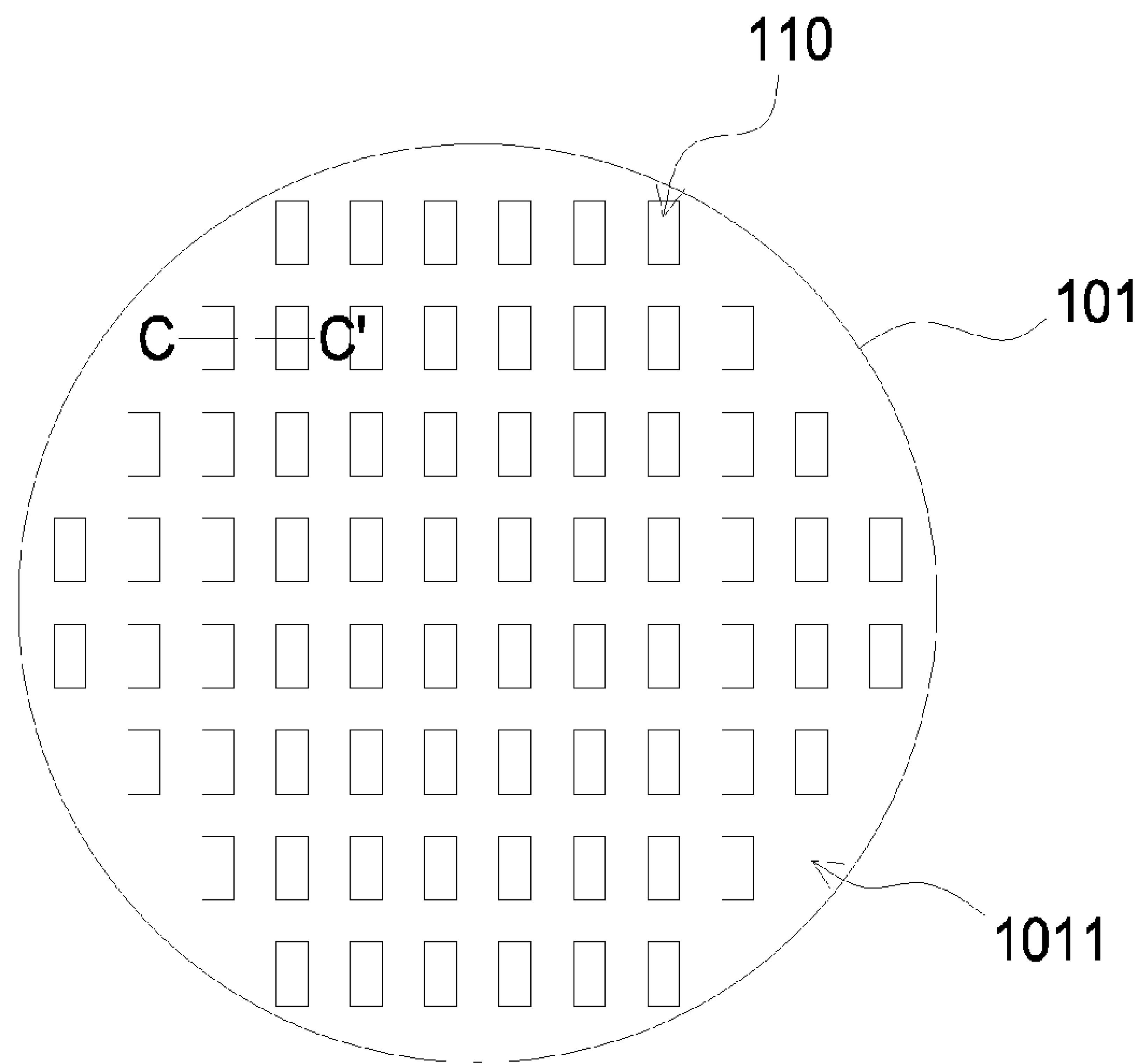



FIG. 6B

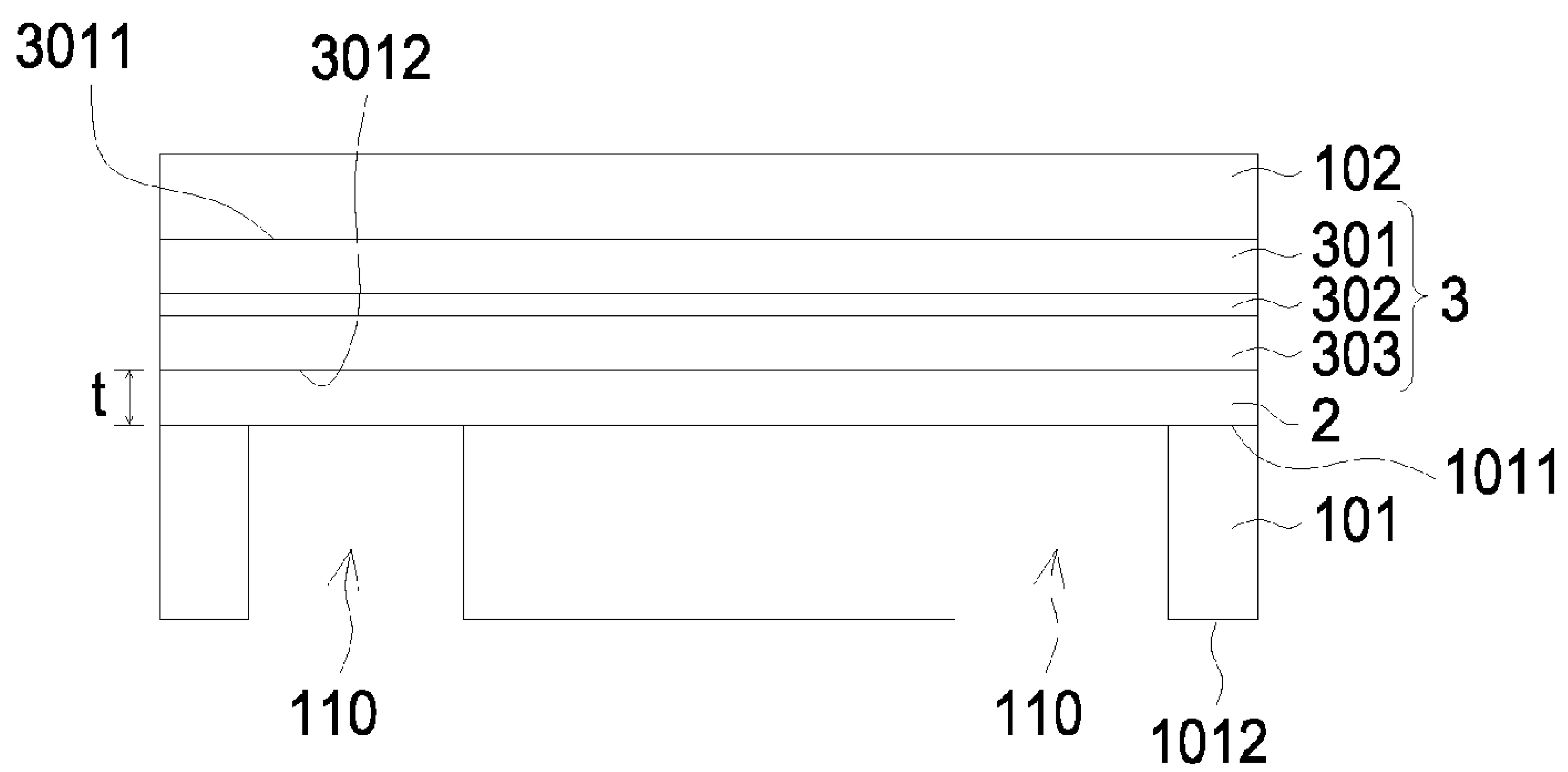



FIG. 6C

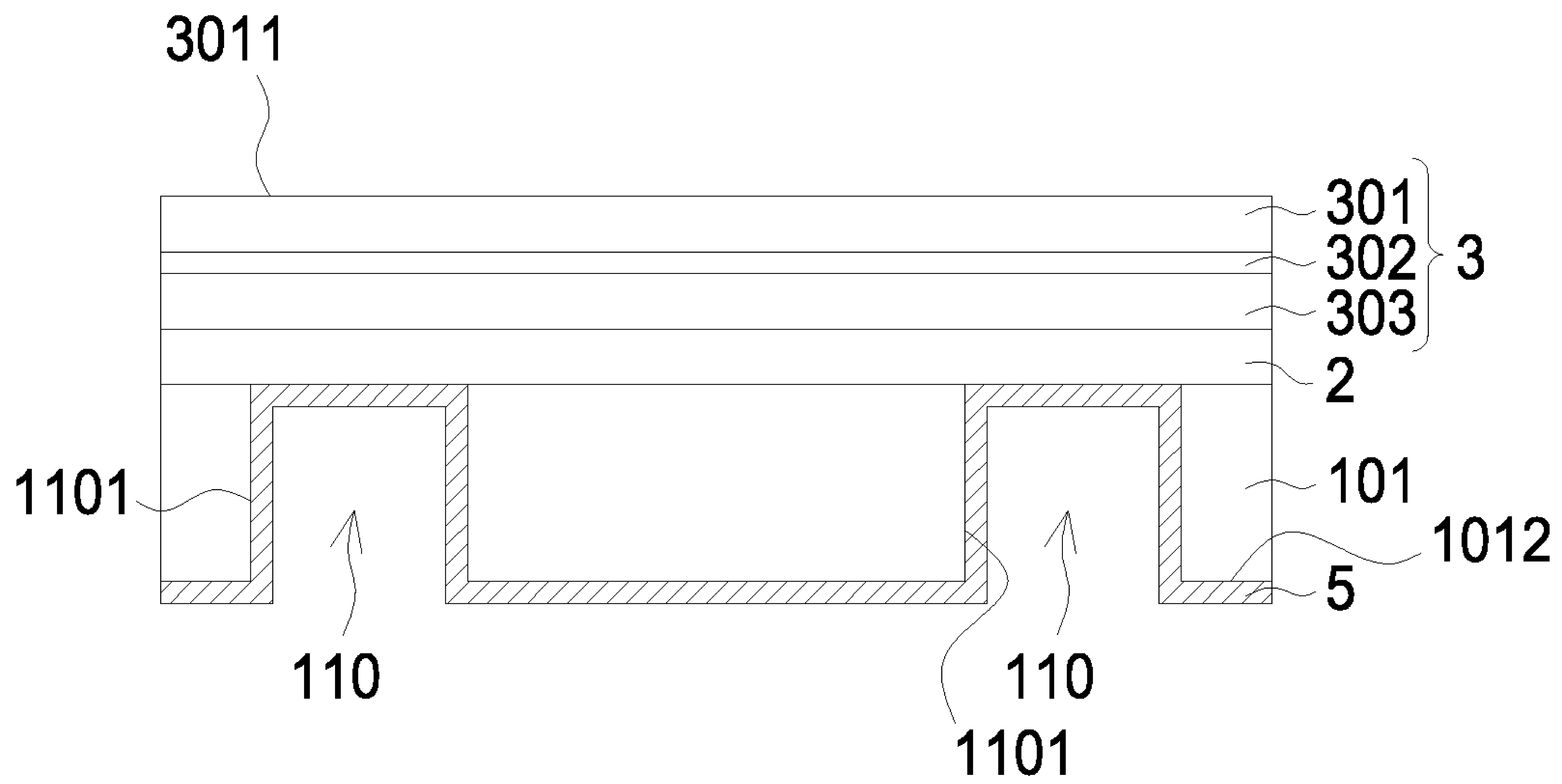
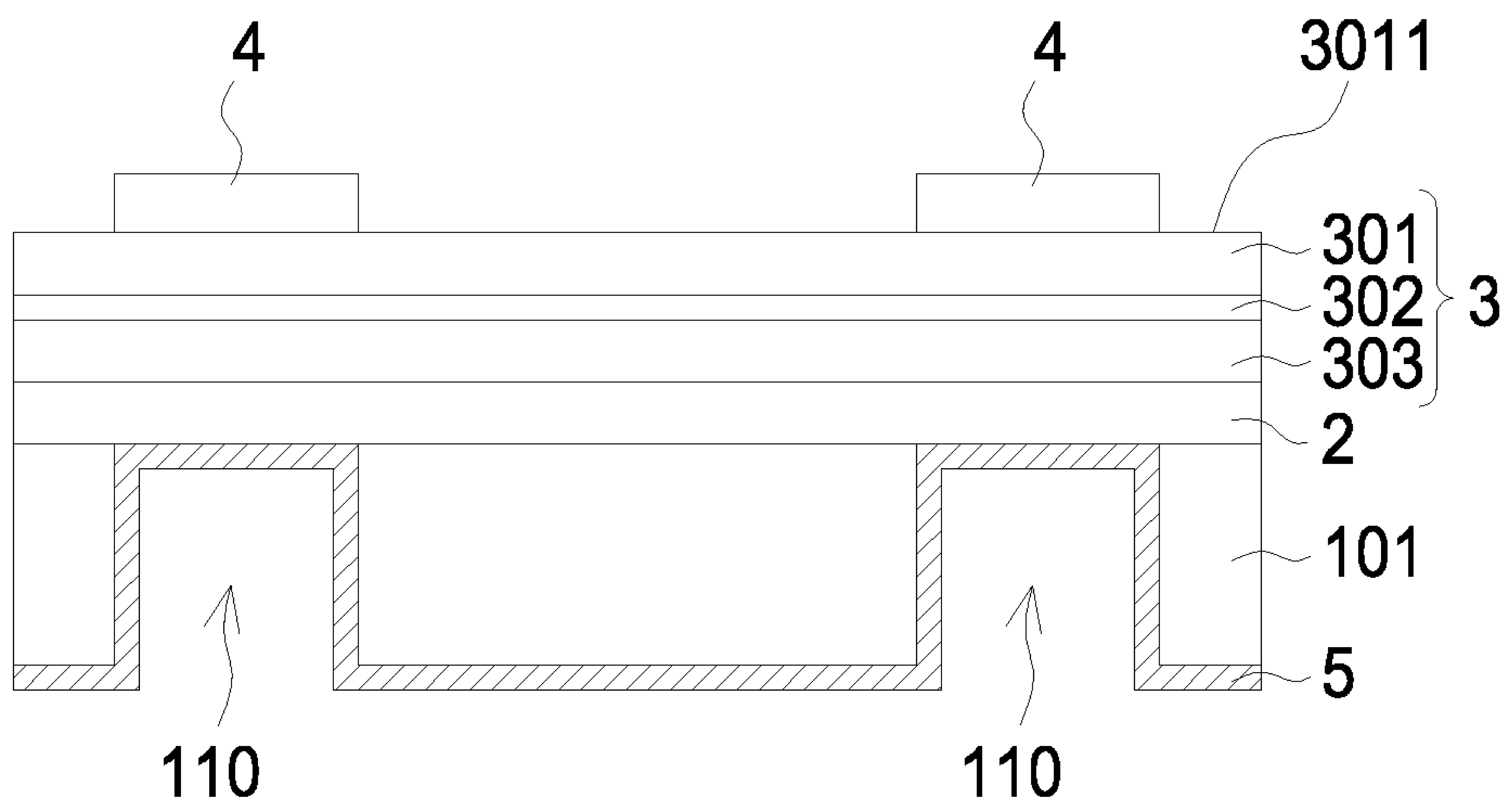



FIG. 6D

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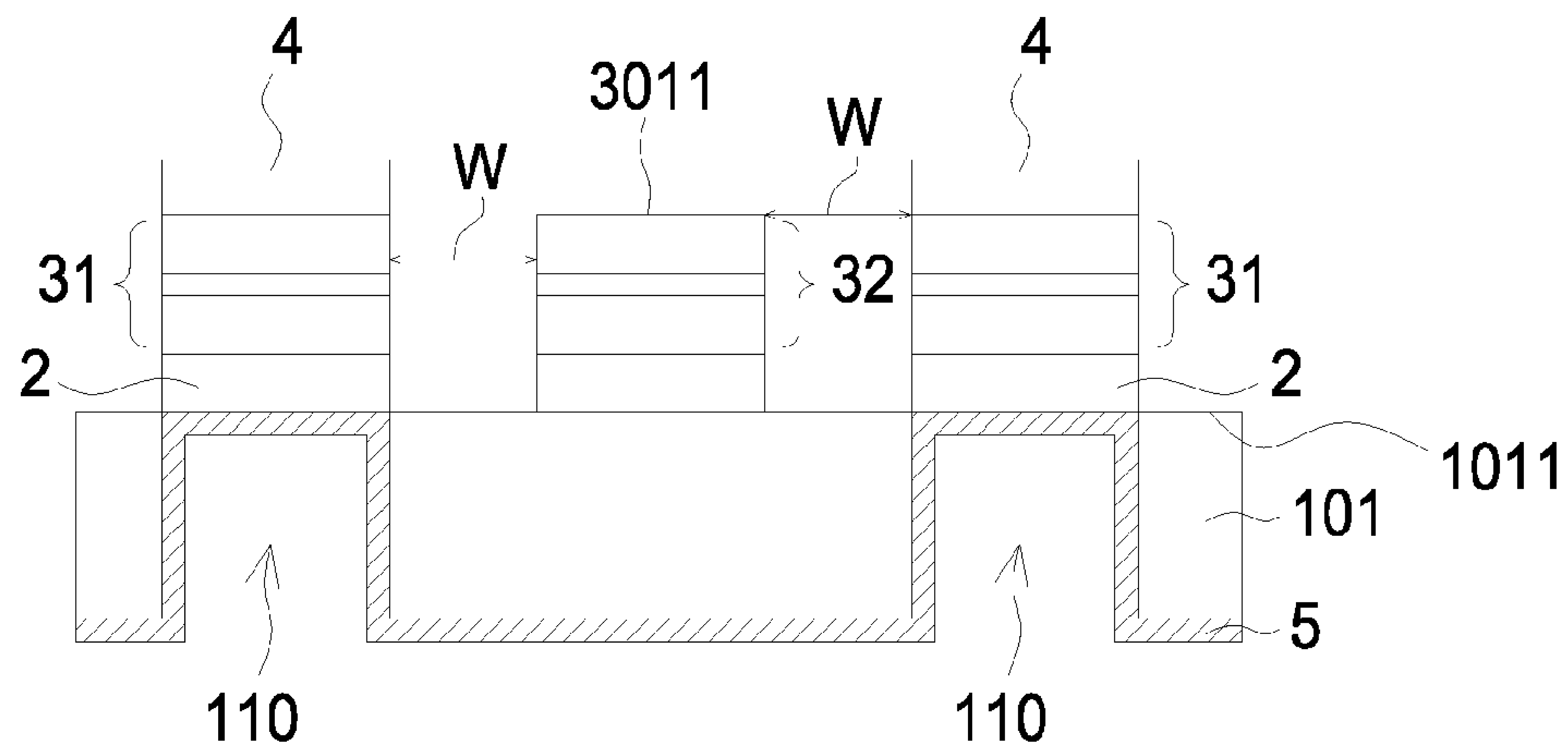


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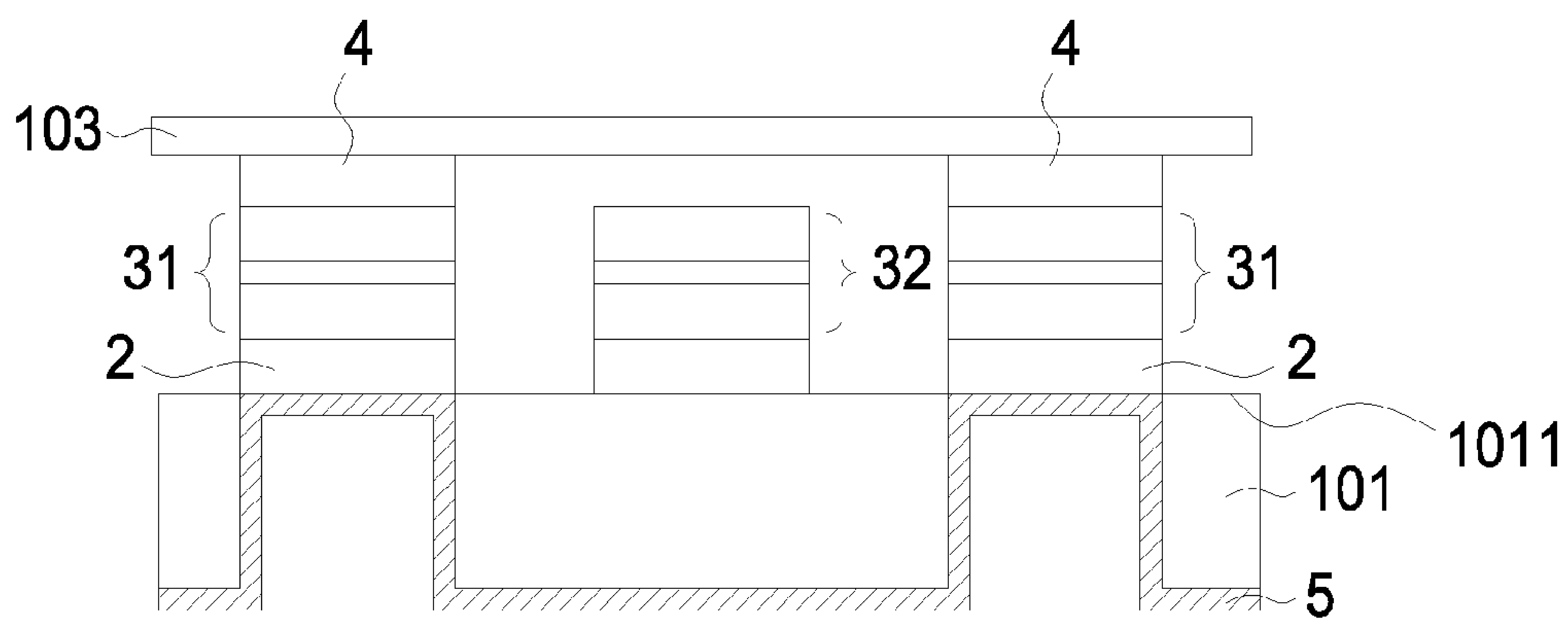


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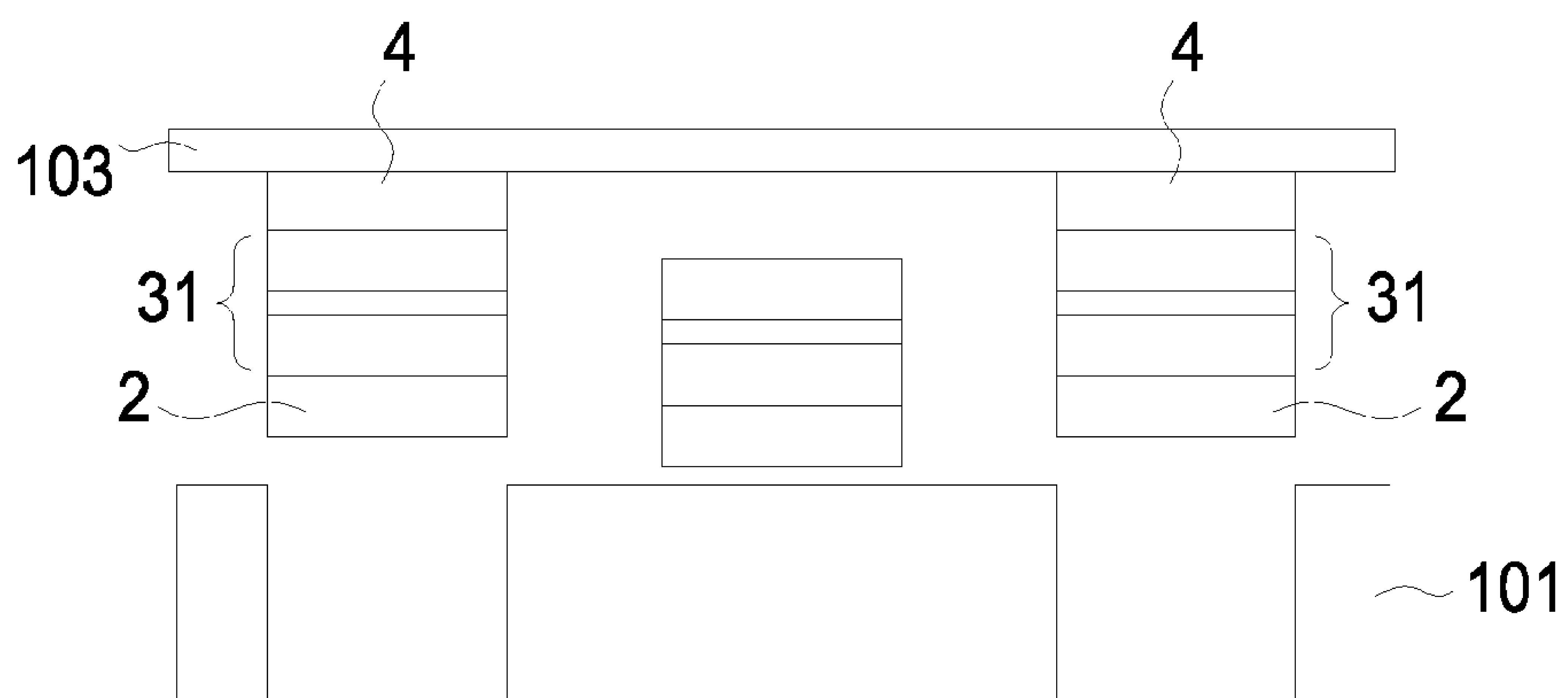



FIG. 6H

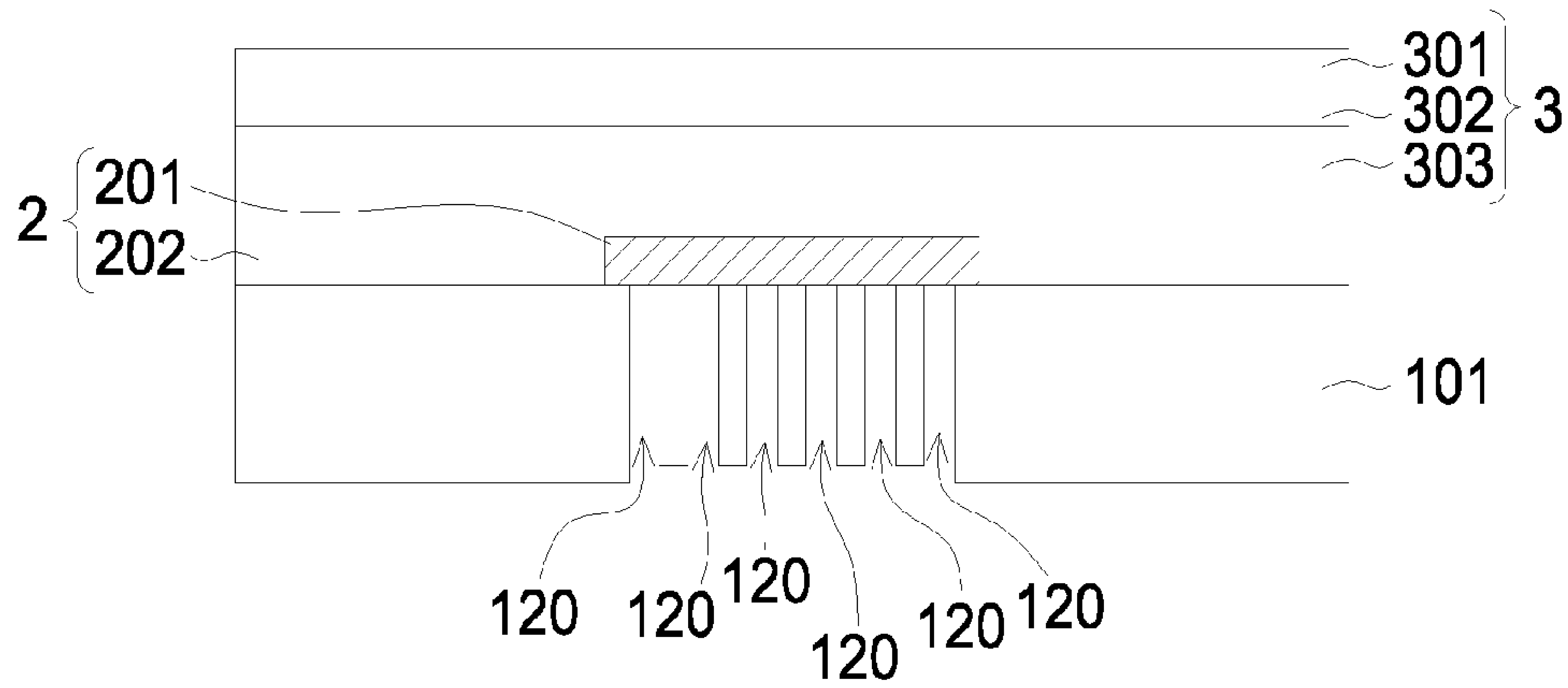



FIG. 7A

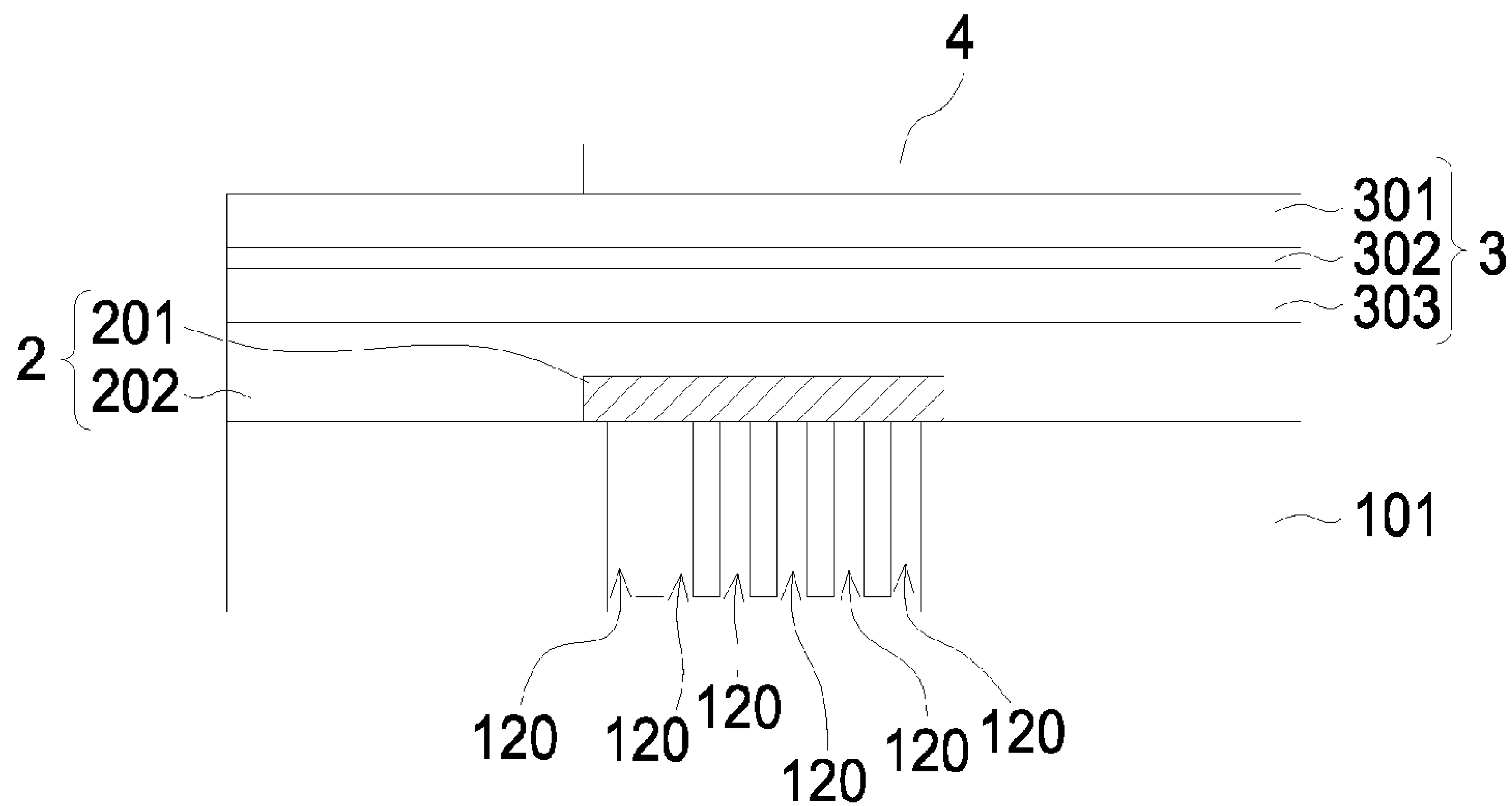



FIG. 7B

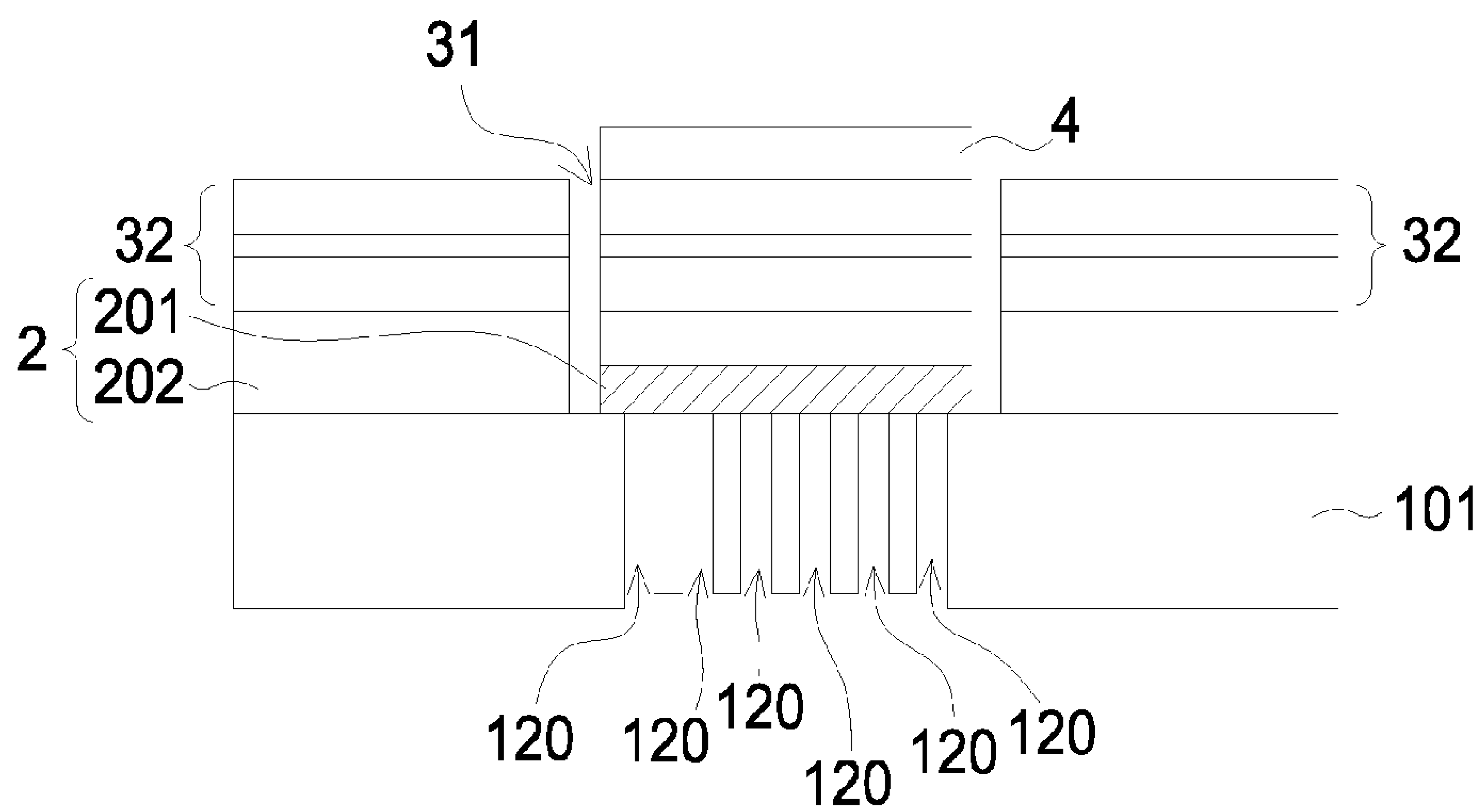



FIG. 7C

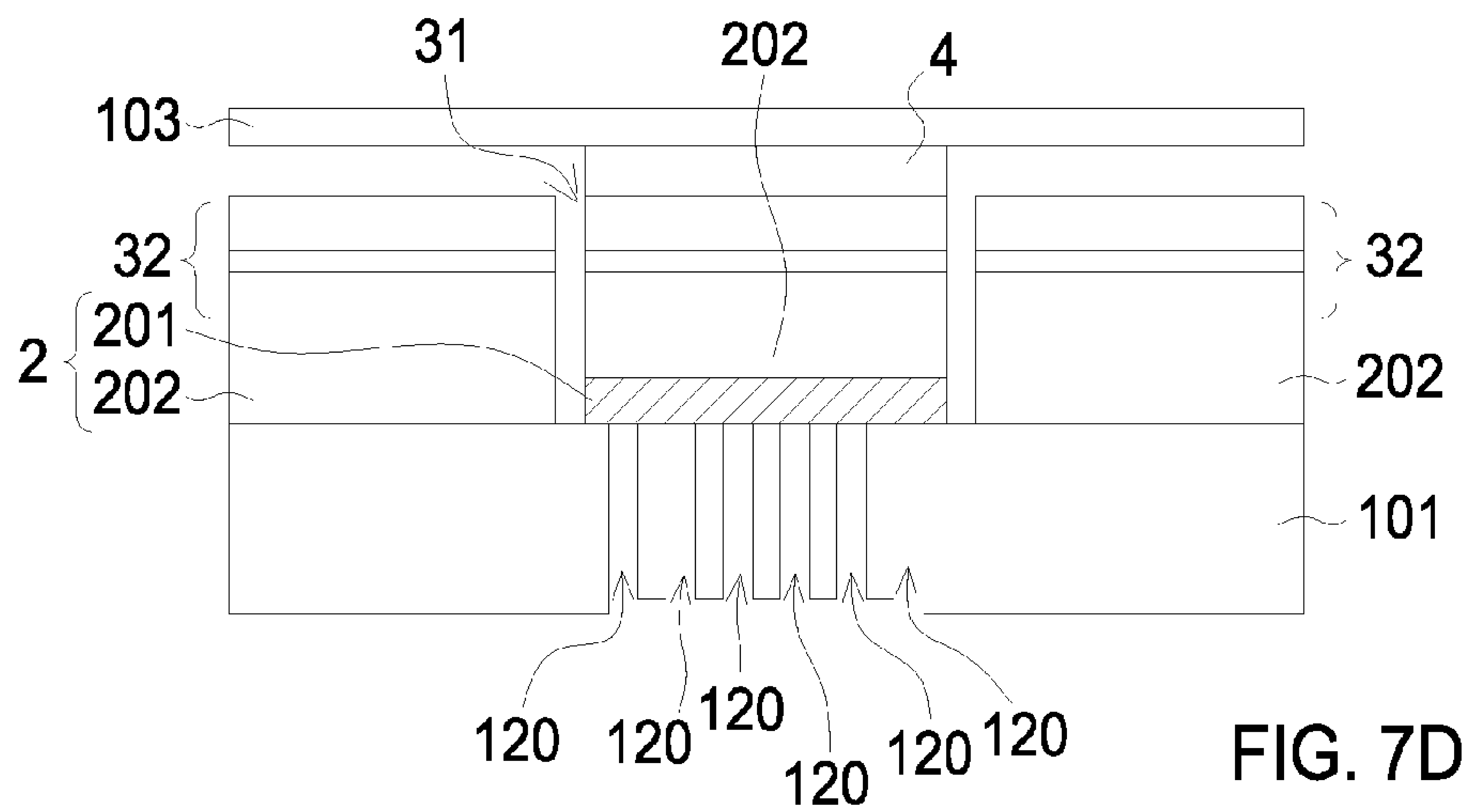



FIG. 7D

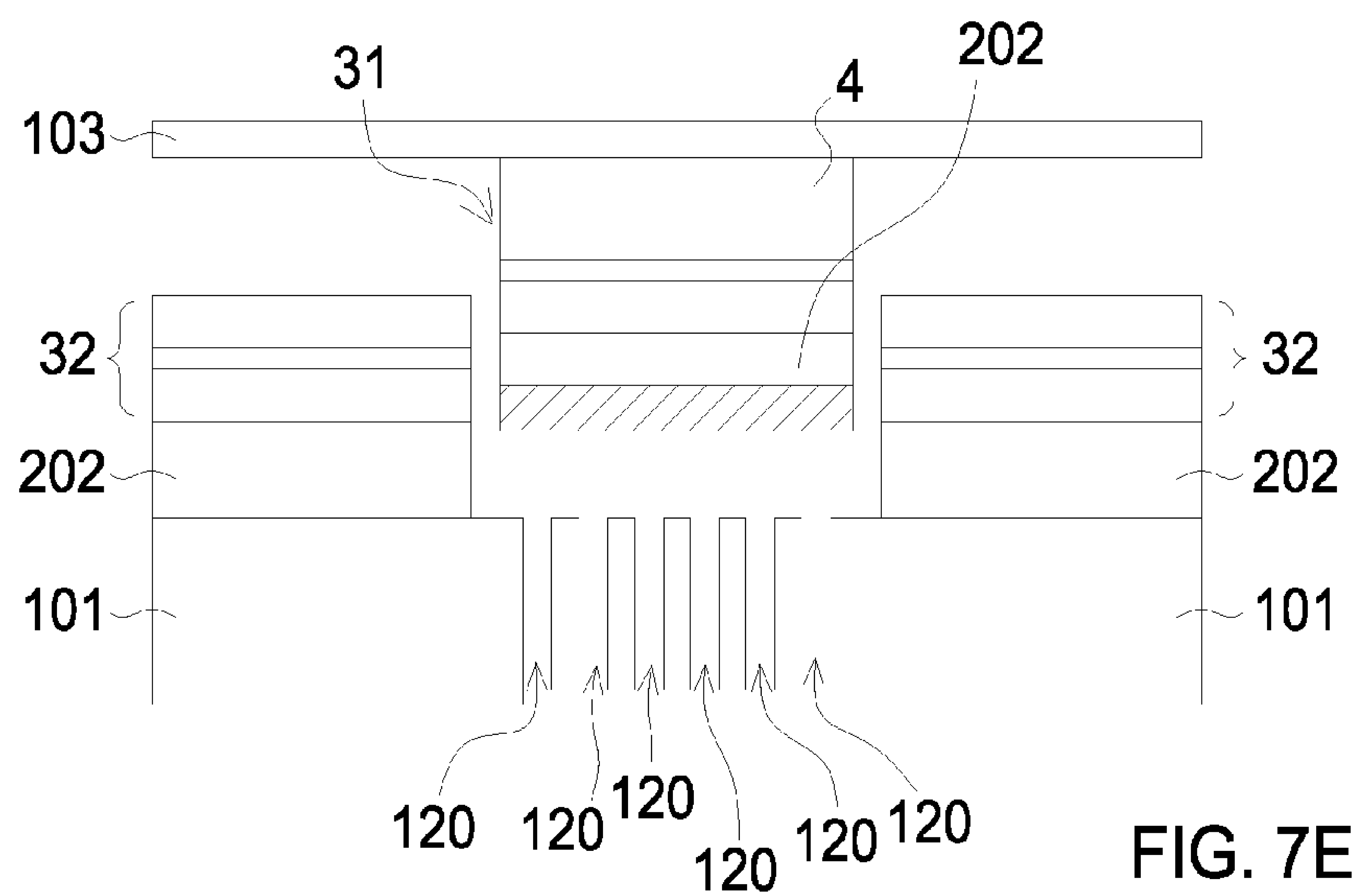



FIG. 7E

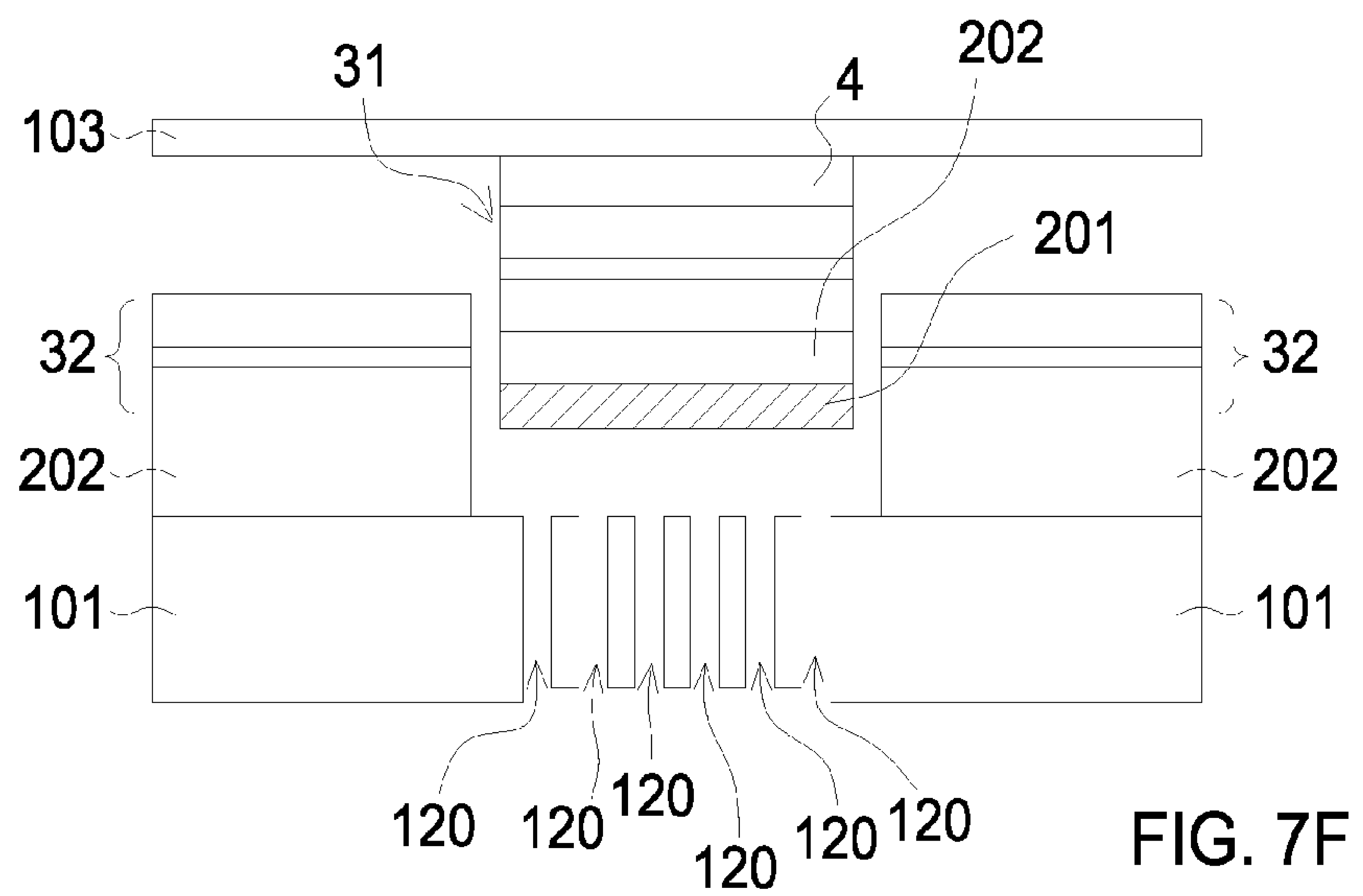



FIG. 7F

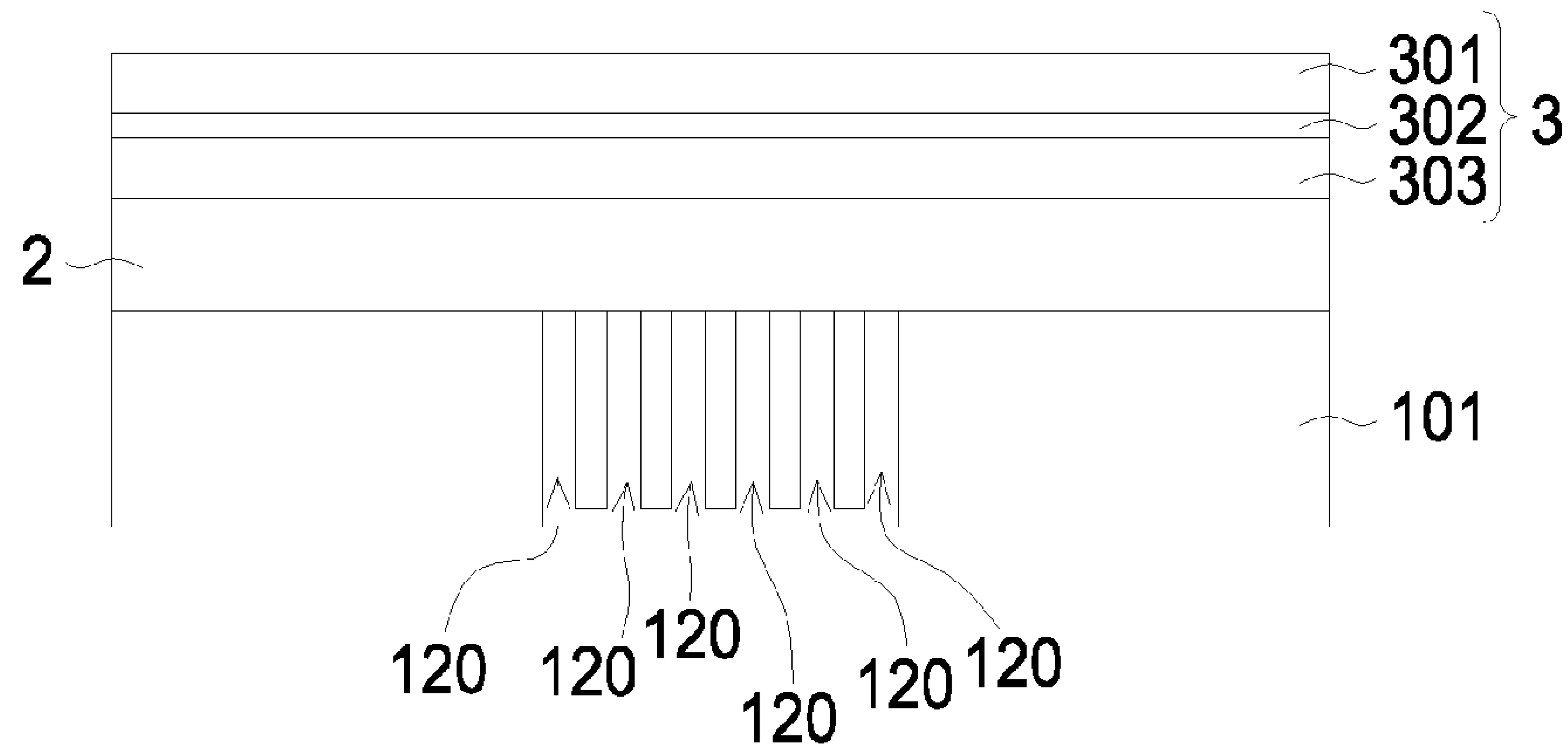



FIG. 8A

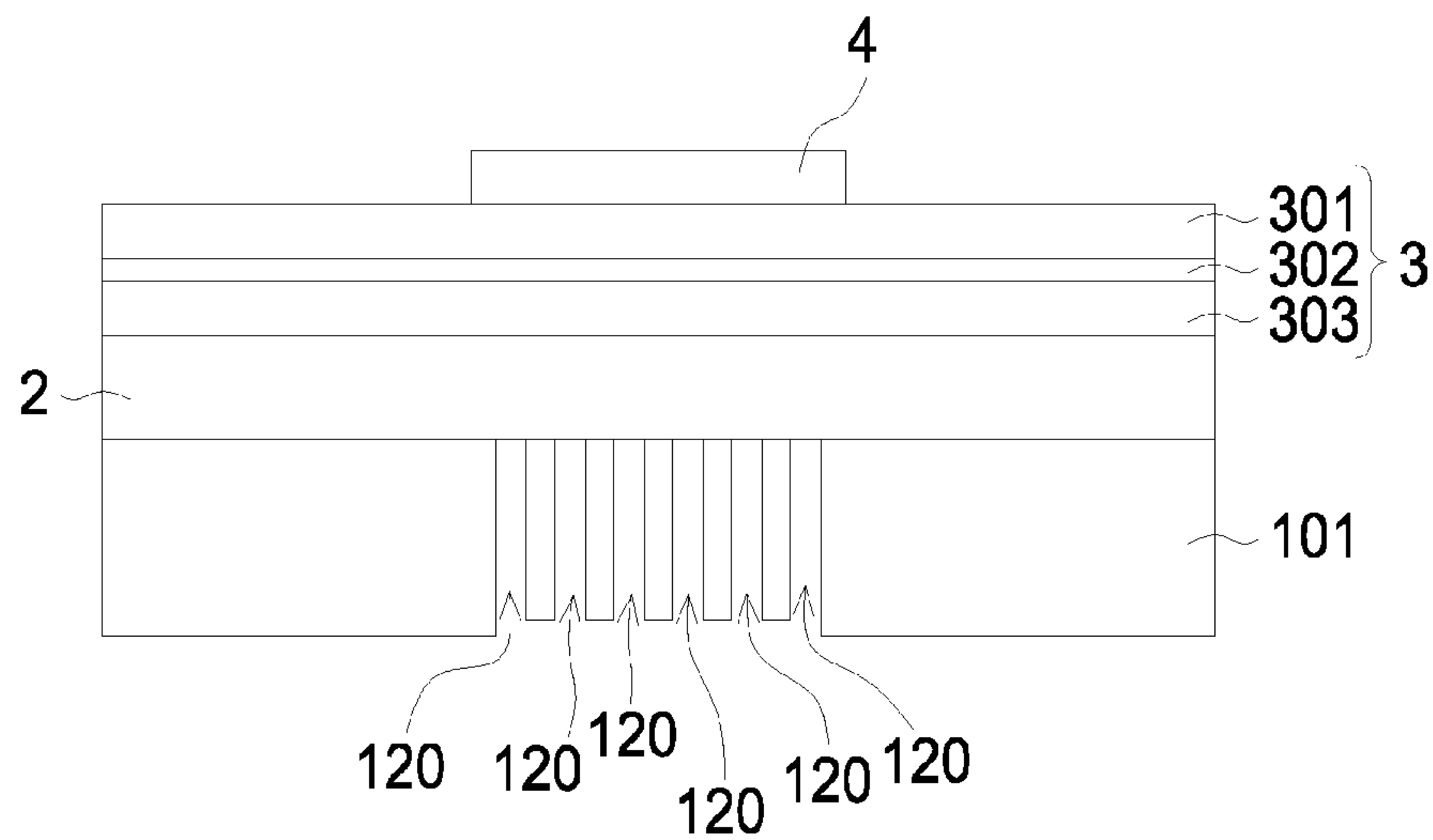



FIG. 8B

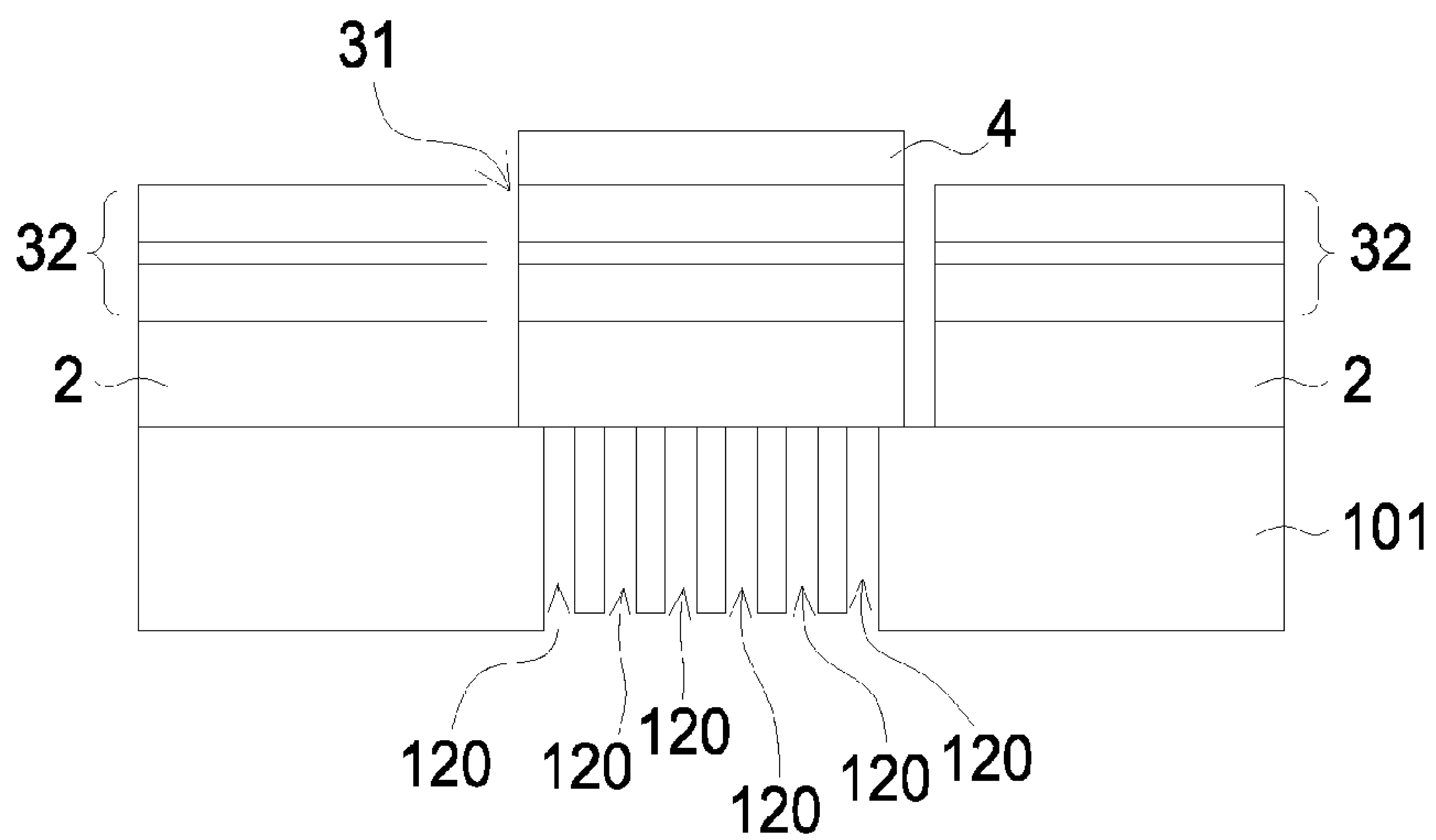



FIG. 8C

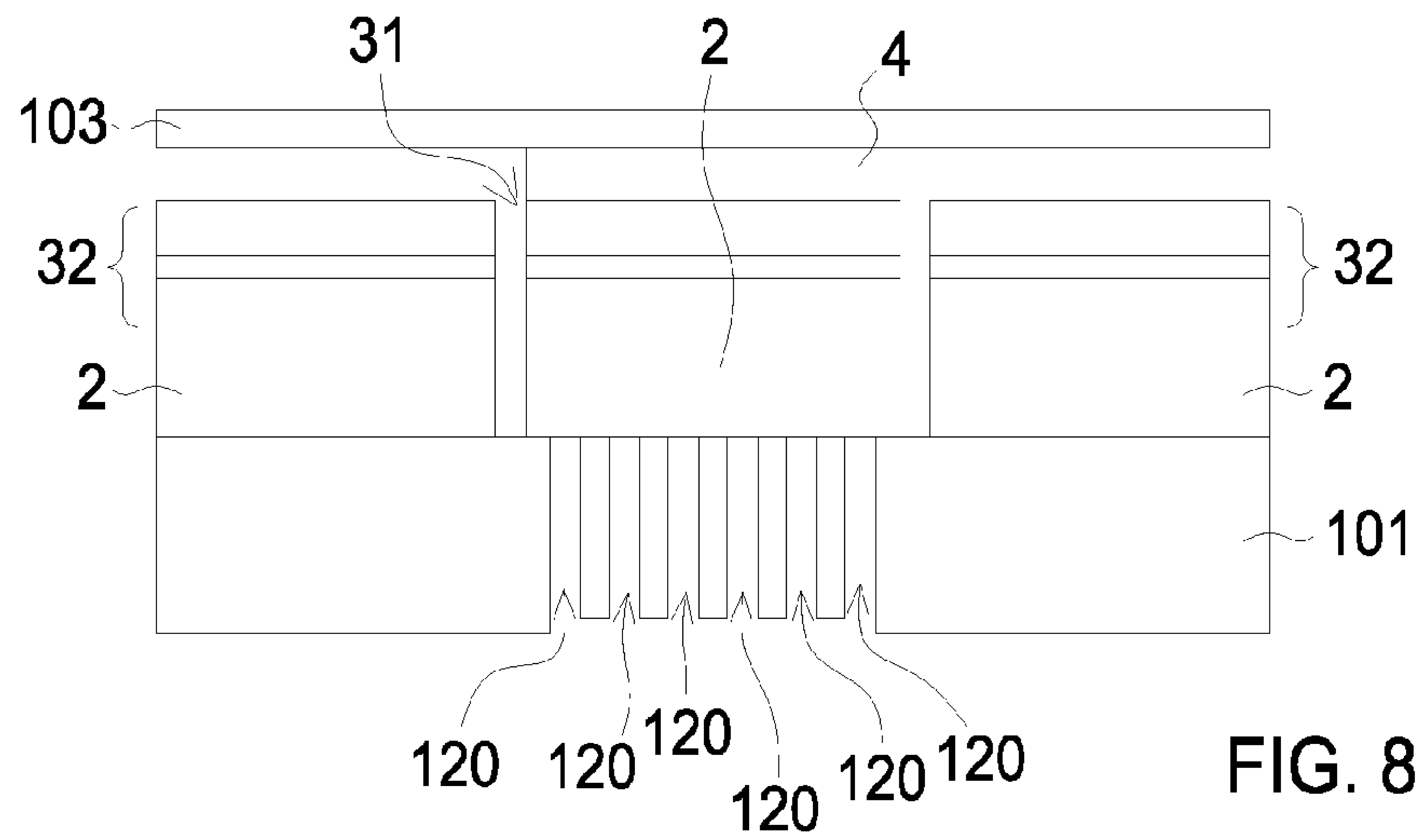
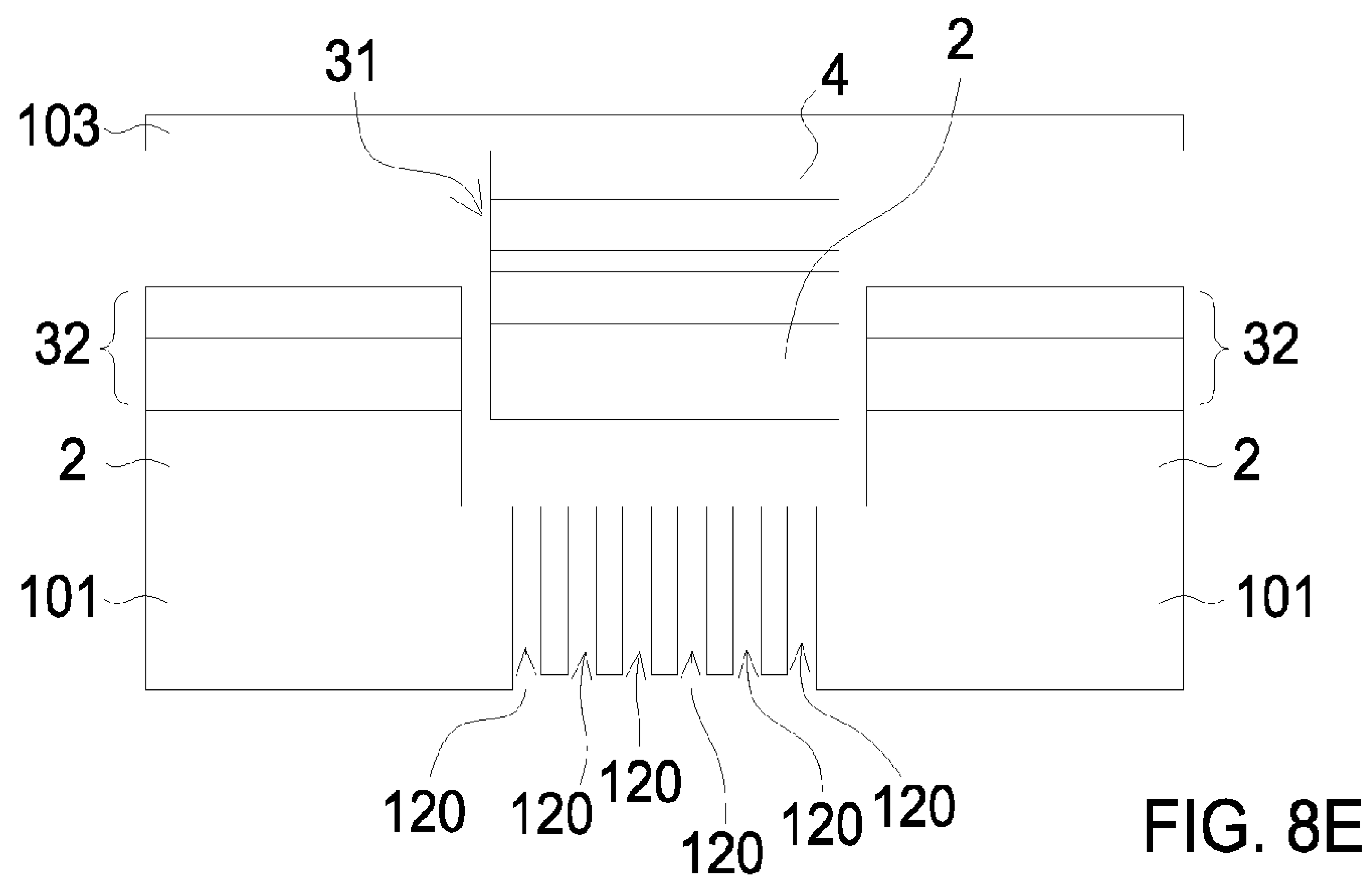



FIG. 8D

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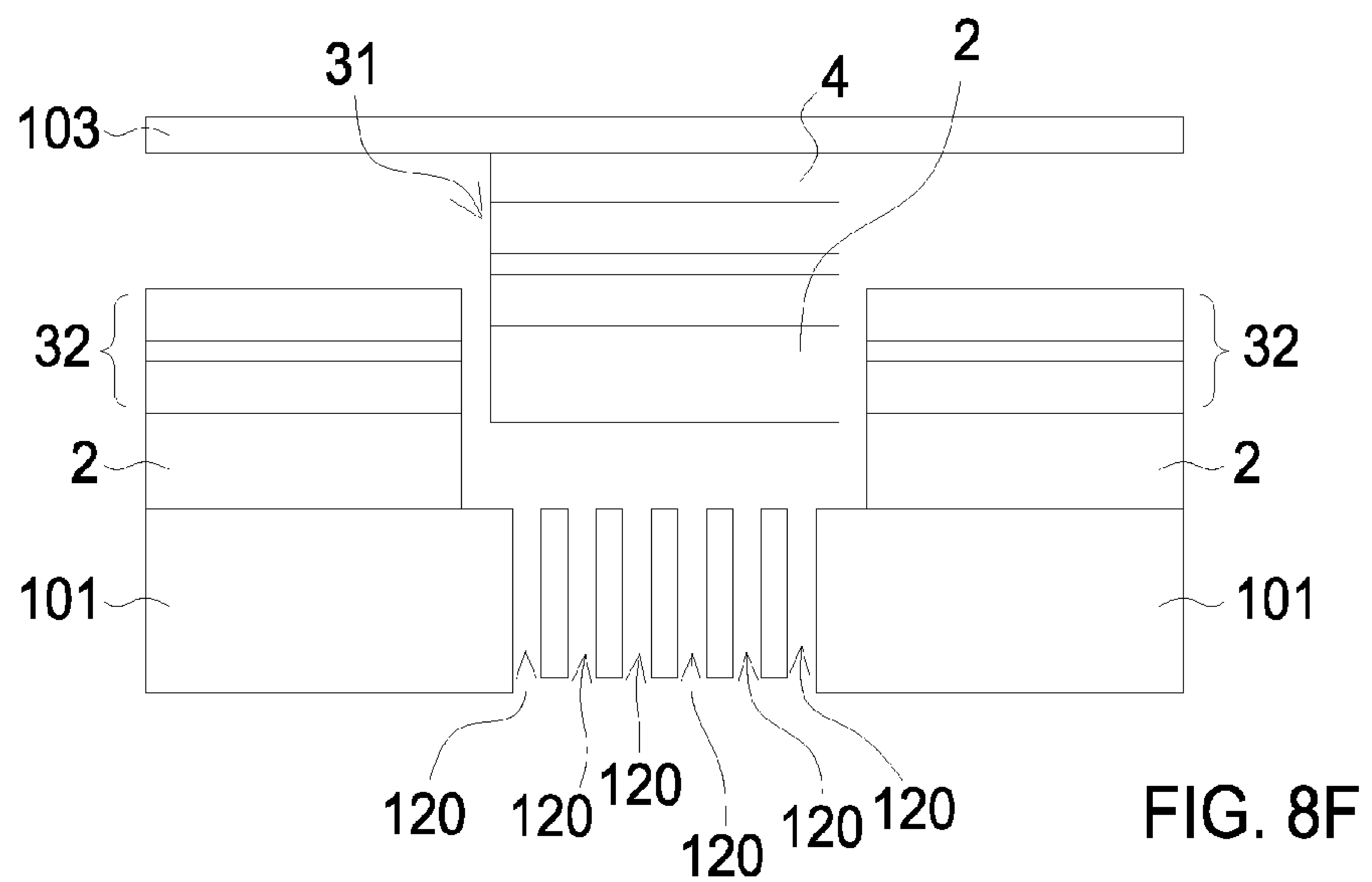


FIG. 8F

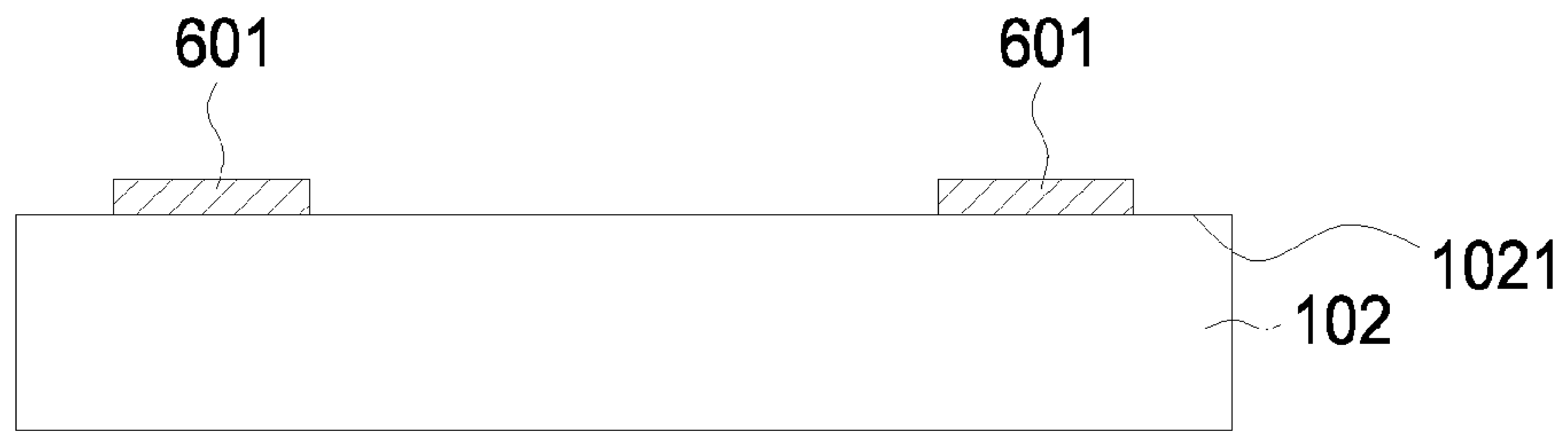


FIG. 9A

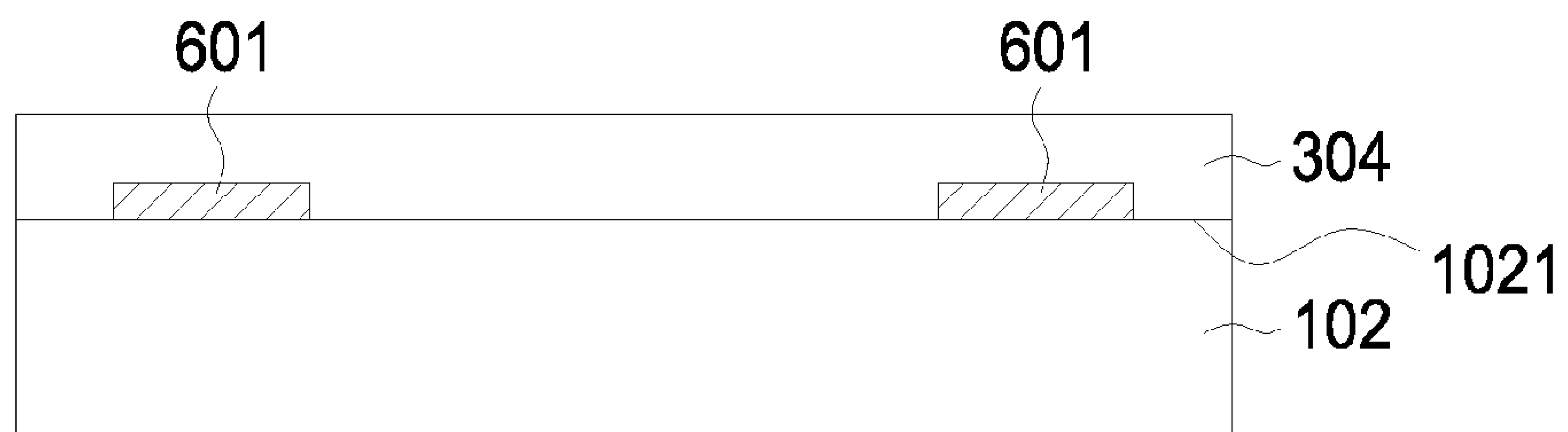


FIG. 9B

FIG. 9C

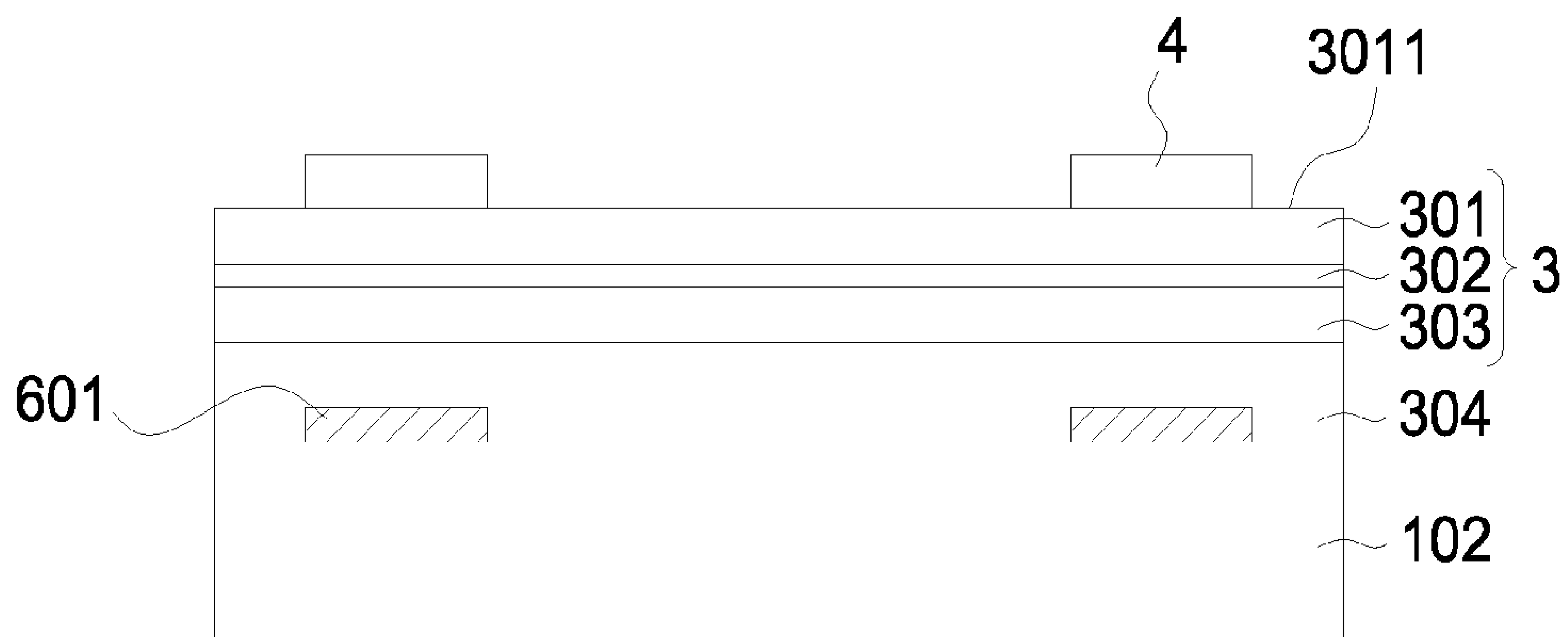


FIG. 9D

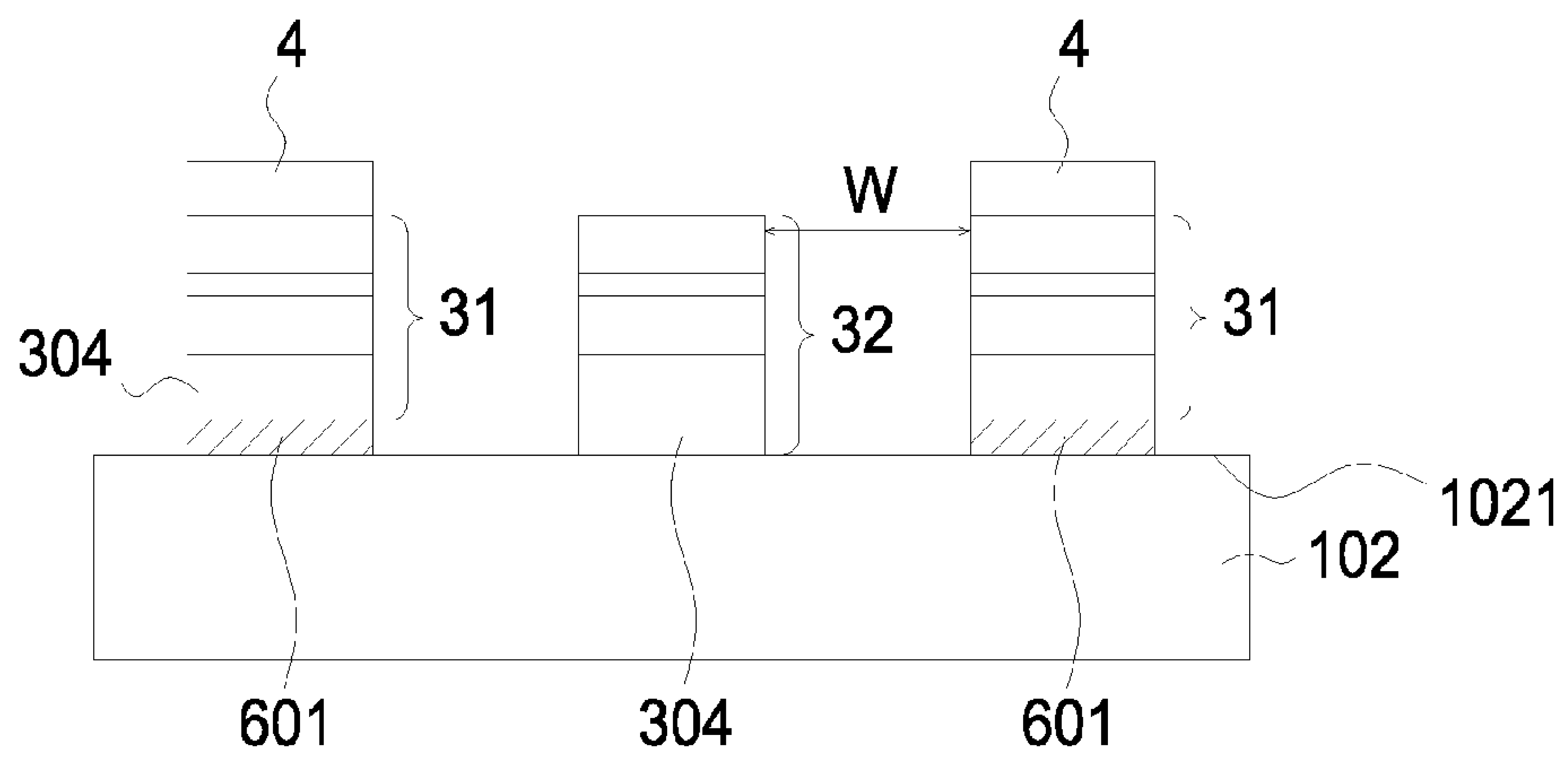


FIG. 9E

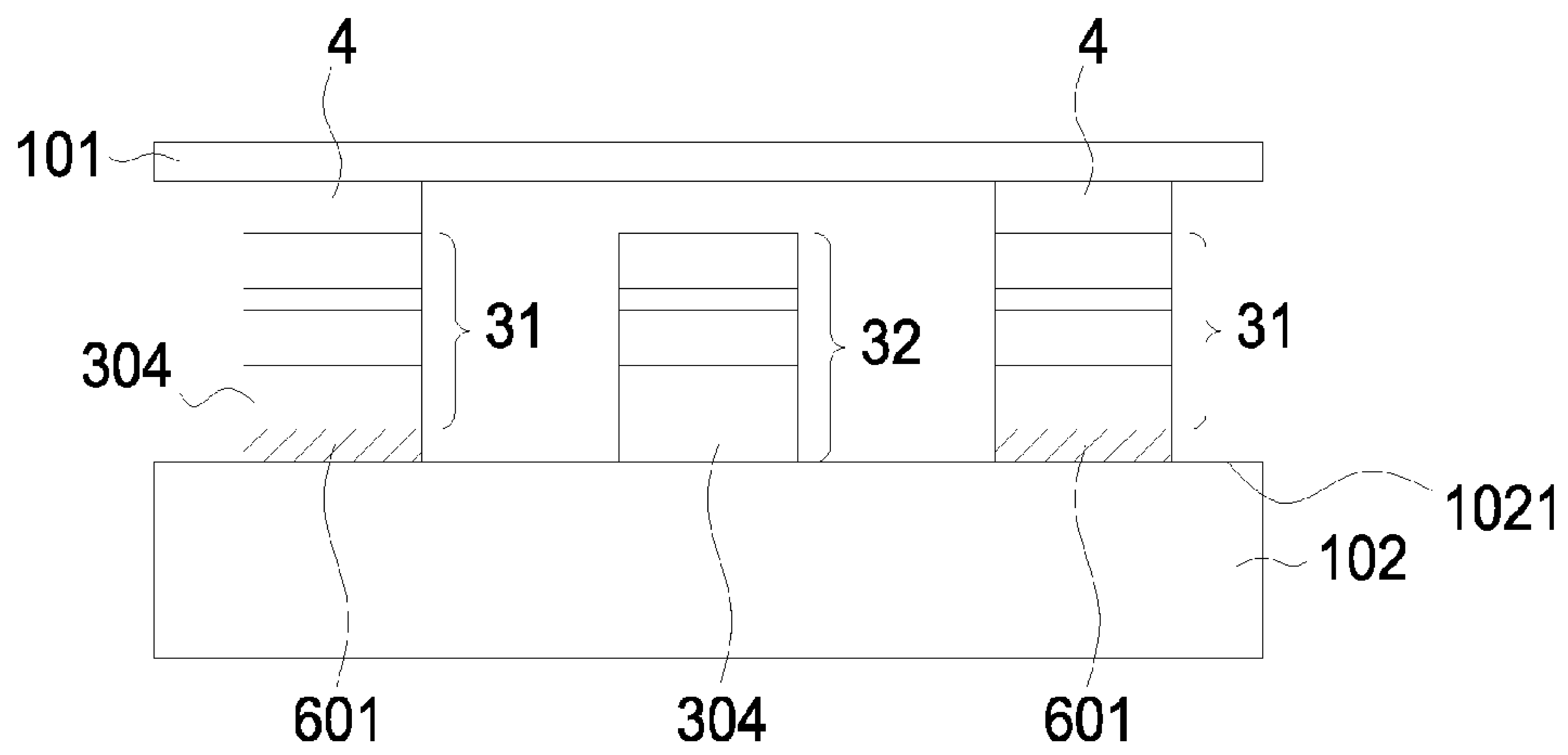


FIG. 9F

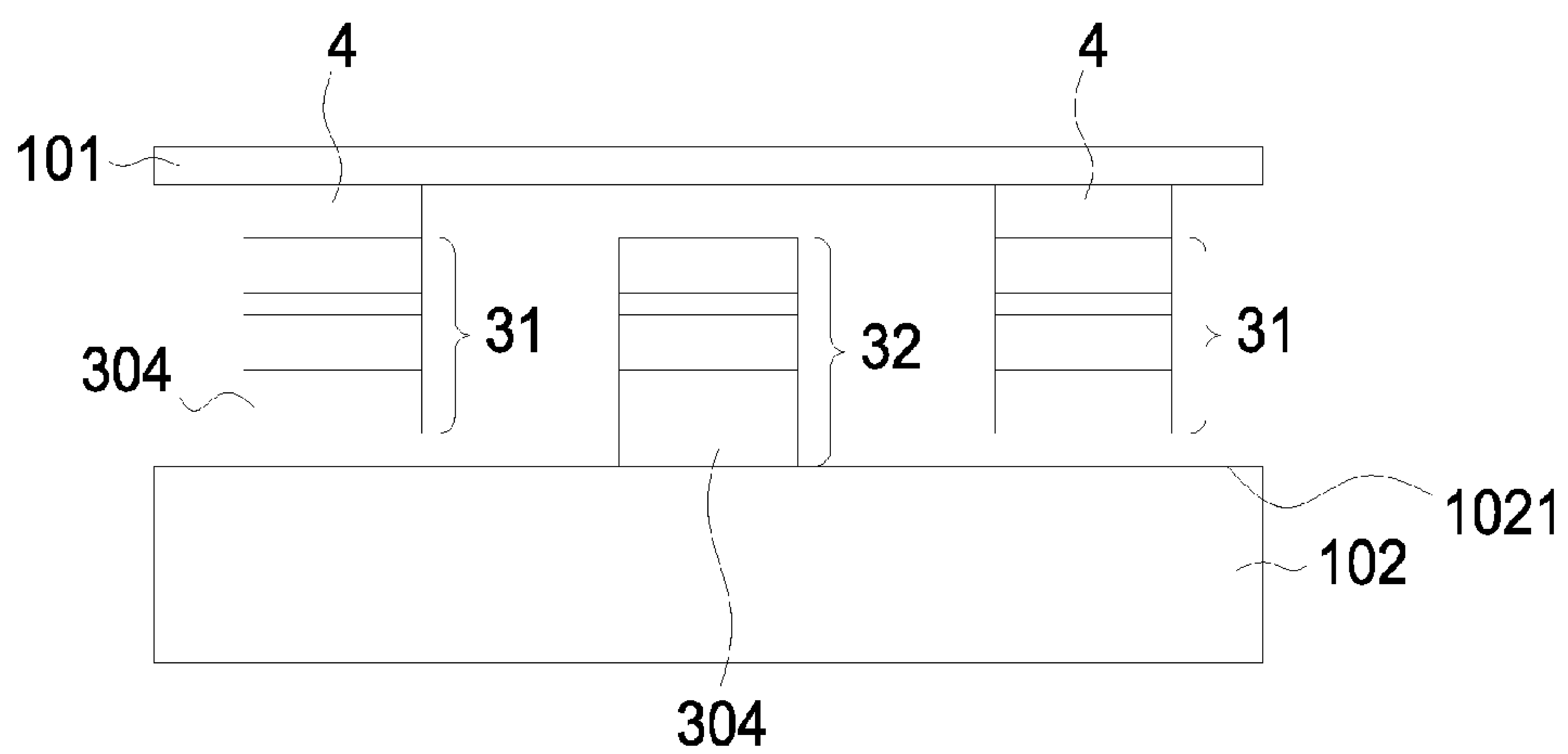


FIG. 9G

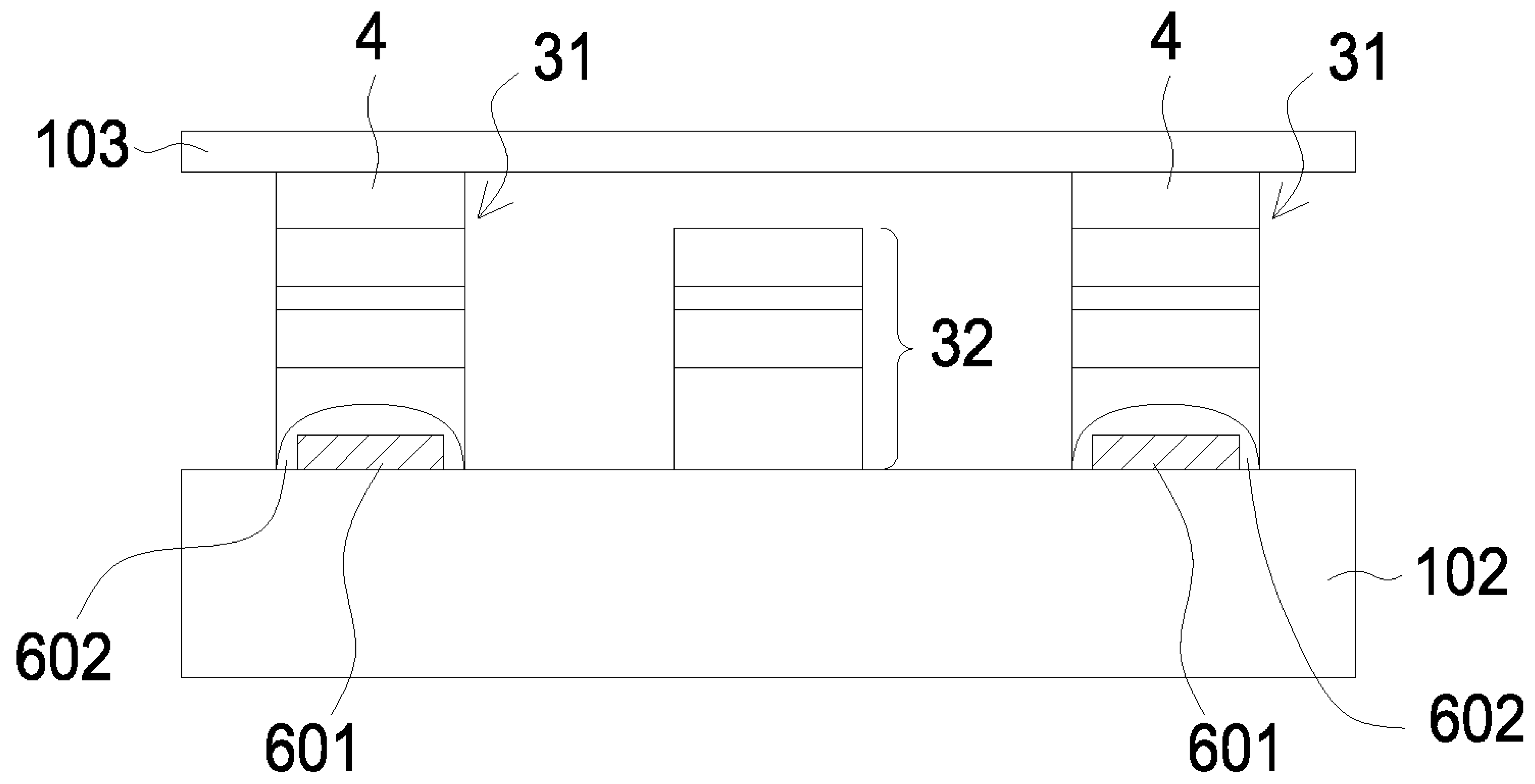


FIG. 9H

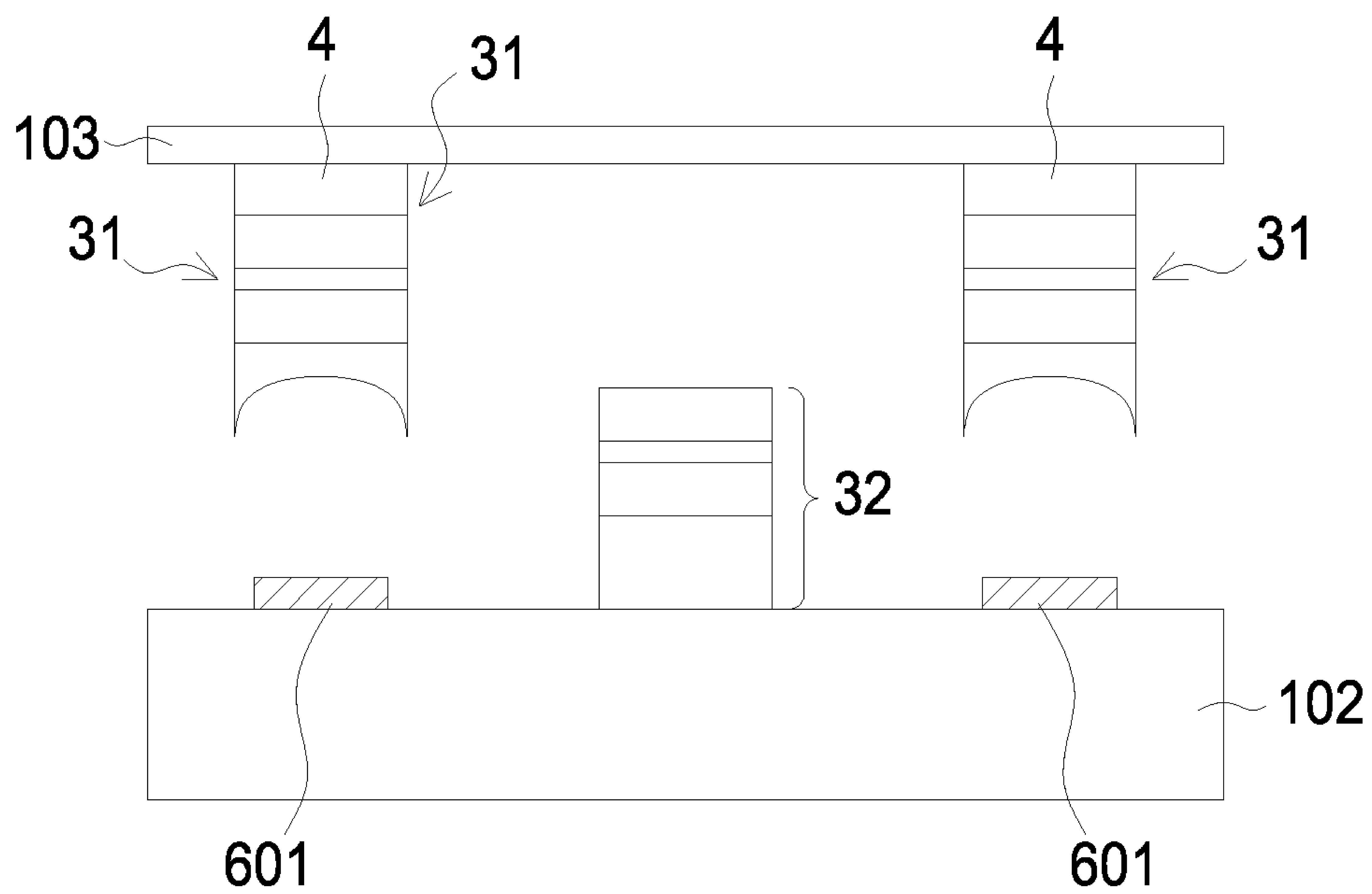


FIG. 9I

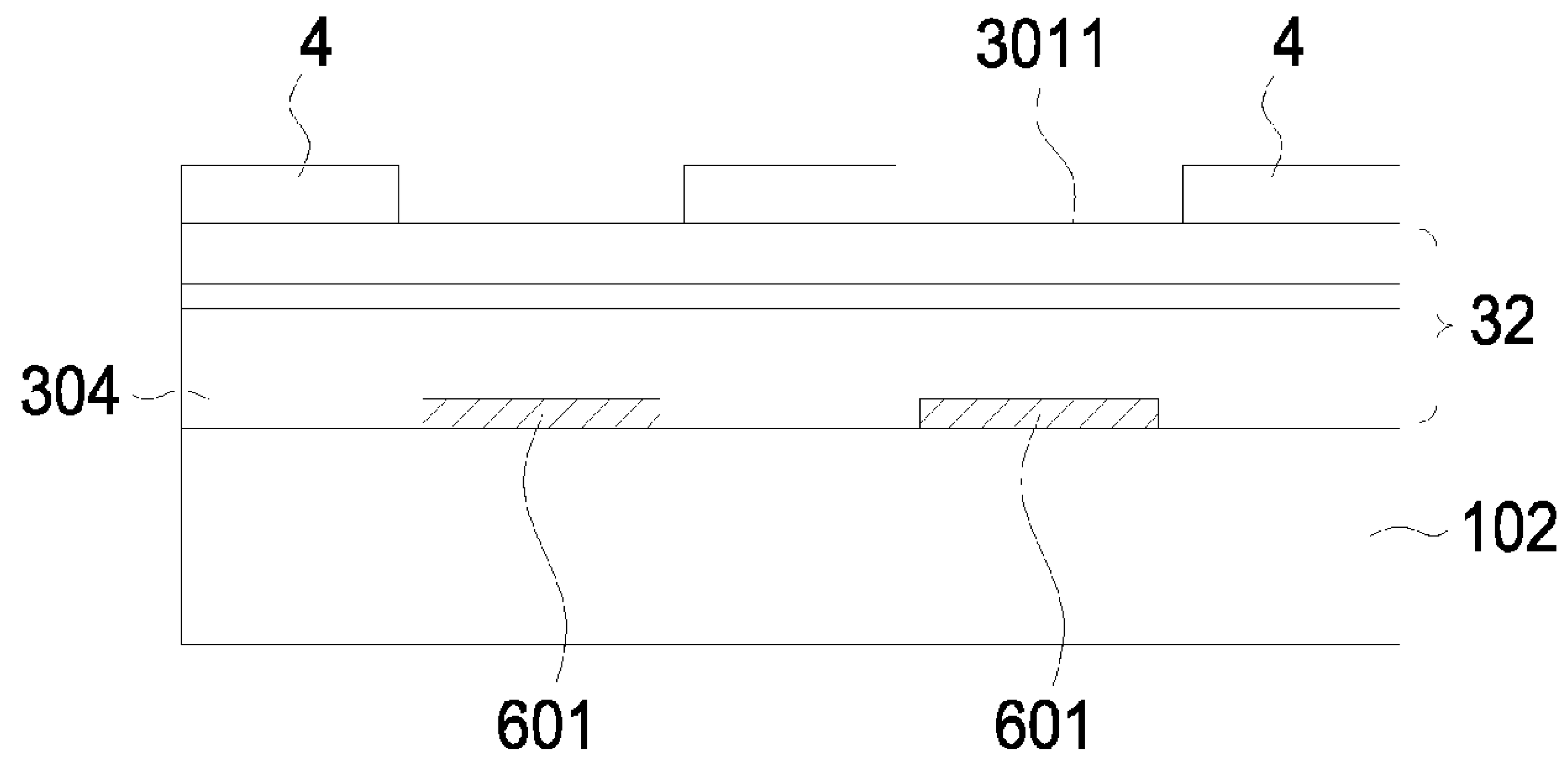


FIG. 10A

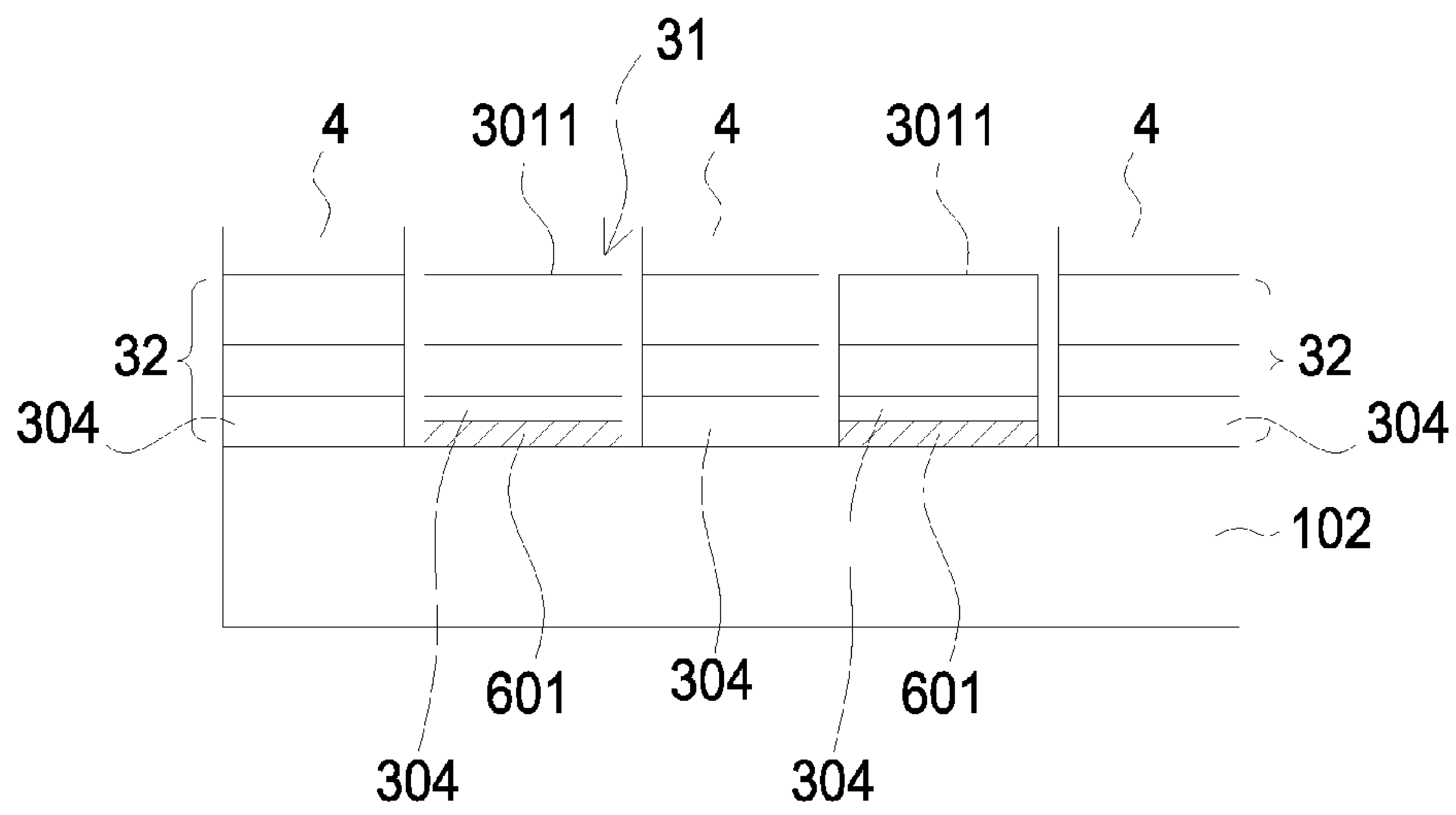


FIG. 10B

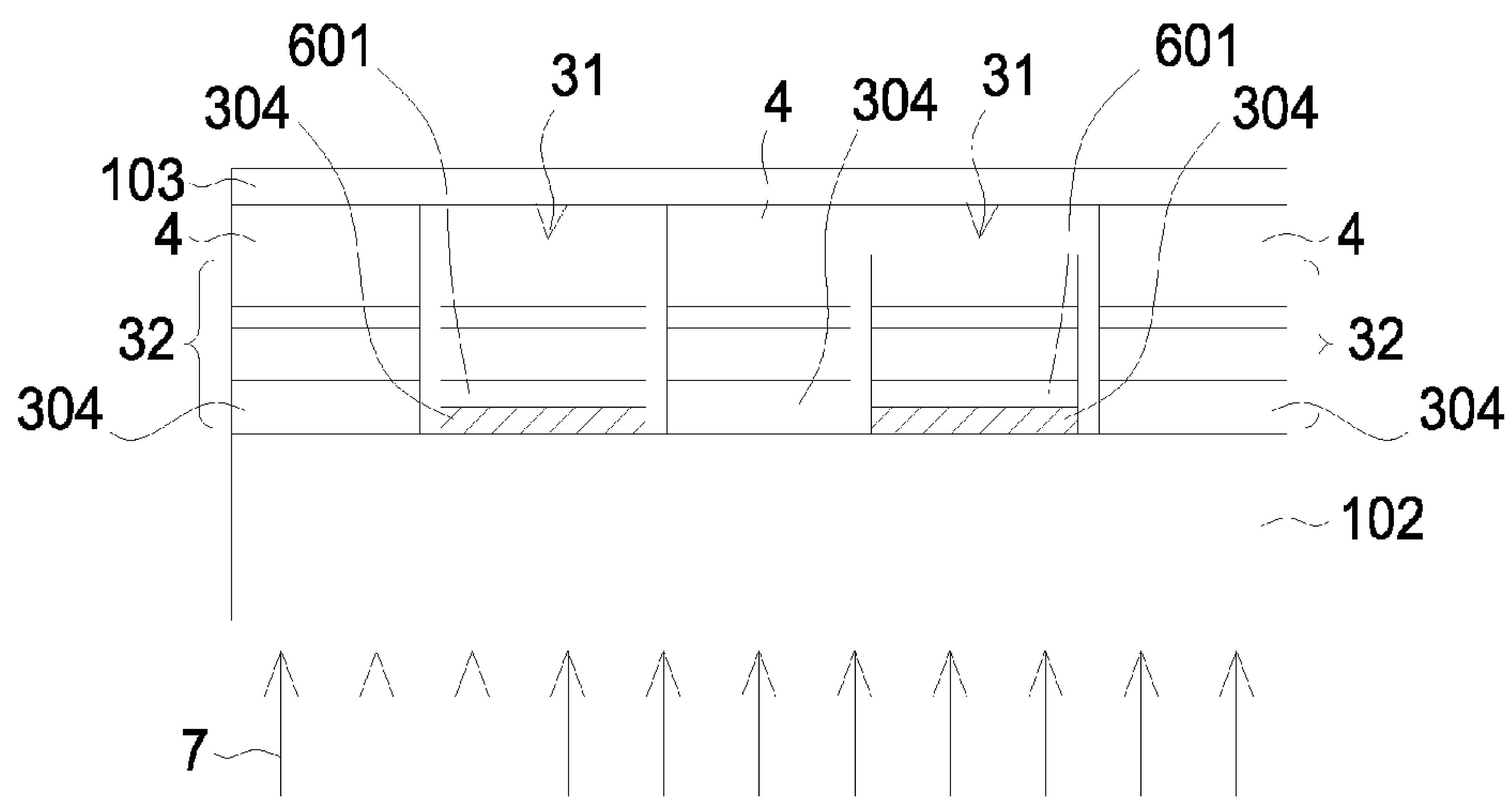


FIG. 10C

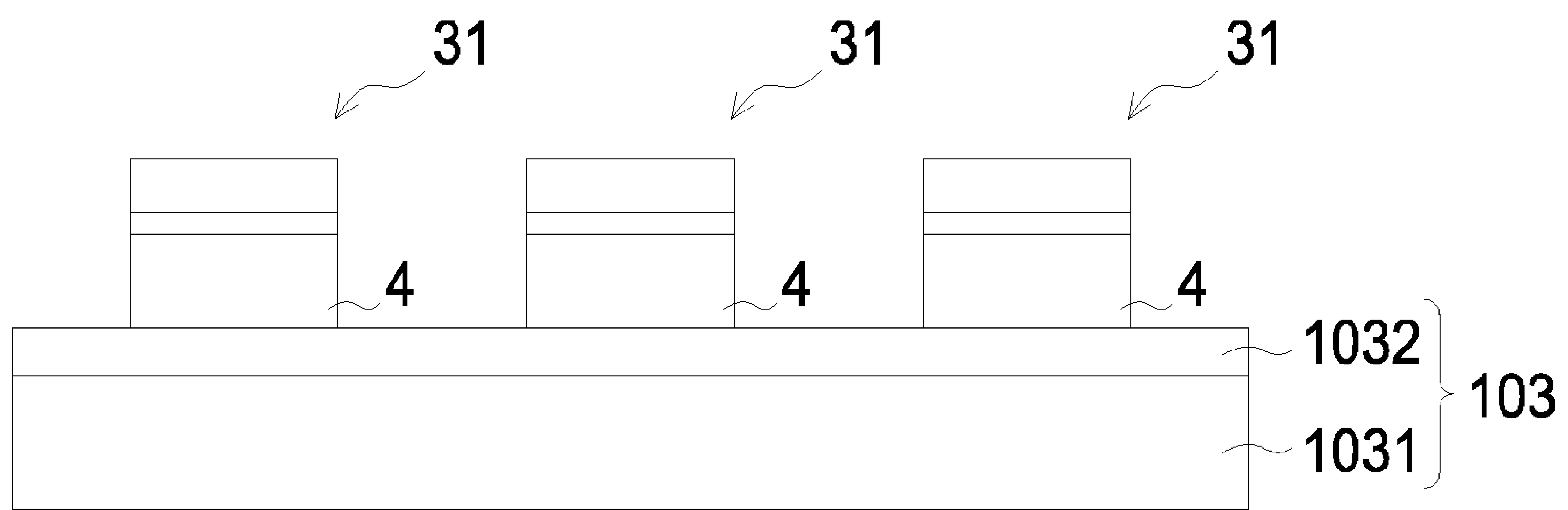


FIG. 11A

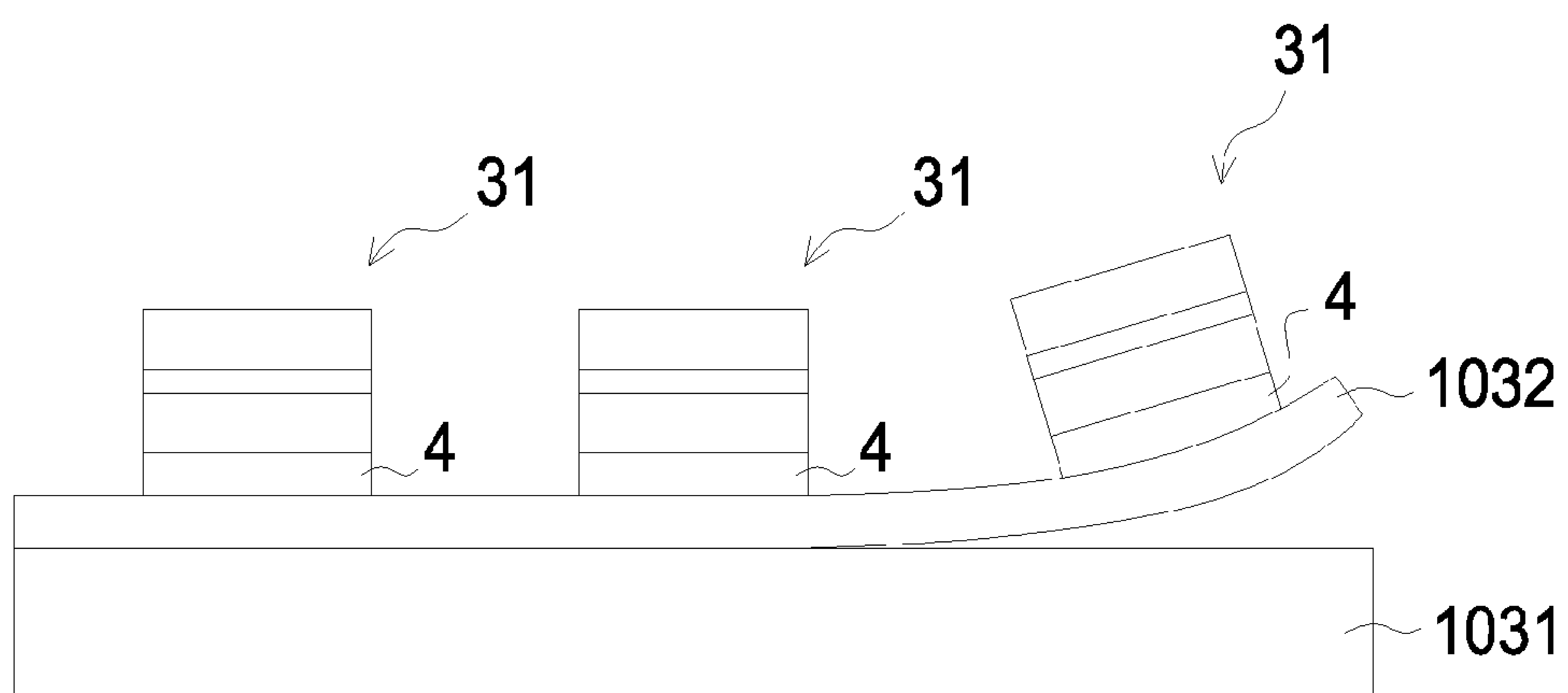


FIG. 11B

# METHOD OF SELECTIVELY TRANSFERRING SEMICONDUCTOR DEVICE

## TECHNICAL FIELD

The application is related to a method of manufacturing a optoelectronic semiconductor device.

## DESCRIPTION OF BACKGROUND ART

As technology developed, optoelectronic semiconductor devices have contributed a lot to energy transmission and conversion. For example, optoelectronic semiconductor devices can be used in system operation such as optical fiber communication system, optical storage system, and military system. According to the energy conversion mode, optoelectronic semiconductor devices can be classified as three categories: conversion from electrical power to light such as light-emitting diode and laser diode; conversion from light to electrical signal such as optical detector; and conversion from light into electrical power such as solar cell.

Growth substrate is important for forming a optoelectronic semiconductor device. Semiconductor epitaxial structure of the optoelectronic semiconductor device is formed on and supported by the growth substrate. Therefore, the quality of the optoelectronic semiconductor device is determined by a suitable growth substrate.

However, a suitable growth substrate sometimes is not suited to be a support substrate for the optoelectronic semiconductor device. For example, in order to obtain a high-quality semiconductor epitaxial structure for a light-emitting diode that can emit red light, the opaque GaAs substrate is usually preferred as the growth substrate for its lattice constant is the most close to that of the semiconductor epitaxial structure for red light-emitting diode. But, as the light-emitting diode is used for emitting light, the opaque growth substrate blocks the light and therefore decreases the light-emitting efficiency of the light-emitting diode in operation.

In order to satisfy the different conditions of the growth substrate and the support substrate required for different optoelectronic semiconductor devices, the technique of transferring substrate is developed. To be more specific, the semiconductor epitaxial structure is firstly formed on the growth substrate and then the semiconductor epitaxial structure is transferred to the support substrate. After the support substrate is bonded with the semiconductor epitaxial structure, the removal of the growth substrate is the key technique in the process of substrate transfer.

The method of removing the growth substrate mainly comprises dissolving method such as wet etching, physical method such as polishing and cutting, or the method of forming a sacrificial layer between the semiconductor epitaxial structure and the growth substrate in advance and then removing the sacrificial layer by etching. However, both of the wet etching method and the physical method such as polishing and cutting, damage the growth substrate. Furthermore, considering the importance of the environmental protection and the energy conservation, it is wasteful if the growth substrate cannot be reused.

## SUMMARY OF THE DISCLOSURE

A method of selectively transferring semiconductor devices comprises the steps of providing a substrate having a first surface and a second surface; providing a plurality of semiconductor epitaxial stacks on the first surface, wherein each of the plurality of semiconductor epitaxial stacks comprises a first semiconductor epitaxial stack and a second semiconductor epitaxial stack, and the first semiconductor epitaxial stack is apart from the second semiconductor epitaxial stack, and wherein a adhesion between the first semiconductor epitaxial stack and the substrate is different from a adhesion between the second semiconductor epitaxial stack and the substrate; and selectively separating the first semiconductor epitaxial stack or the second semiconductor epitaxial stack from the substrate.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A to **1**I show the structures corresponding to the steps of a manufacturing process according to the first embodiment;

FIGS. **2**A to **2**H show the structures corresponding to the steps of a manufacturing process according to the second embodiment;

FIGS. **3**A to **3**H show the structures corresponding to the steps of a manufacturing process according to the third embodiment;

FIGS. **4**A to **4**C show the structures according to the fourth embodiment;

FIGS. **5**A to **5**G show the structures corresponding to the steps of a manufacturing process according to the fifth embodiment;

FIGS. **6**A to **6**H show the structures corresponding to the steps of a manufacturing process according to the sixth embodiment;

FIGS. **7**A to **7**F show the structures corresponding to the steps of a manufacturing process according to the seventh embodiment;

FIGS. **8**A to **8**F show the structures corresponding to the steps of a manufacturing process according to the eighth embodiment;

FIGS. **9**A to **9**I show the structures corresponding to the steps of a manufacturing process according to the ninth embodiment;

FIGS. **10**A to **10**C show the structures corresponding to the steps of a manufacturing process according to the tenth embodiment;

FIGS. **11**A to **11**B show the structures corresponding to the steps of a manufacturing process according to one embodiment.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

### First Embodiment

FIGS. **1**A to **1**I show the structures corresponding to the steps of a manufacturing process according to the first embodiment. FIG. **1**A shows the cross-sectional diagram along the dotted line AA' of FIG. **1**B. According to the process for manufacturing the optoelectronic device disclosed in the embodiment of the application, an adhesion substrate **101** with a surface **1011** is provided, and an adhesion structure **2** is formed on the surface **1011**, wherein the adhesion structure **2** has a thickness t. In this embodiment, the thickness t is between 2 μm and 6 μm. The adhesion structure **2** comprises an adhesion layer **202** and a sacrificial layer **201**, wherein the adhesion layer **202** and the sacrificial layer **201** are formed side by side on the surface **1011** and connect to the surface **1011**. FIG. **1**B shows the top view of the adhesion structure **2**, and each of the adhesion

layer **202** and the sacrificial layer **201** has a specific shape. The adhesion substrate **101** comprises an electrically-insulated substrate or an electrically-conductive substrate. The material of electrically-insulated substrate comprises sapphire, diamond, glass, quartz, acryl, $LiAlO_2$ or ceramics; the material of electrically-conductive substrate comprises semiconductor such as Si, GaAs, SiC, GaN and AlN, oxide such as ZnO, metal, or the combination thereof. In this embodiment, the materials of the adhesion layer **202** and the sacrificial layer **201** are different. The material of the adhesion layer **202** comprises BCB. The material of the sacrificial layer **201** comprises organic material or inorganic material, wherein the organic material comprises UV dissociated glue or thermoplastic material, and the inorganic material comprises metal, oxide, or nitride, wherein the UV dissociated glue comprises acrylic acid, unsaturated polyester, epoxy, oxetane or vinyl ether, the thermoplastic comprises nylon, PP, PBT, PPO, PC, ABS or PVC, the metal comprises Ti, Au, Be, W, Al or Ge, the oxide comprises SiOx, and the nitride comprises SiNx.

As shown in FIG. **1**C, a growth substrate **102** is provided and a semiconductor epitaxial stack **3** is formed on the growth substrate **102** by epitaxial growth. Then, the growth substrate **102** and the semiconductor epitaxial stack **3** are adhered to the surface **1011** of the adhesion substrate **101** through the adhesion structure **2** by heating and pressing method, wherein both of the adhesion layer **202** and the sacrificial layer **201** contact the semiconductor epitaxial stack **3**. Because the materials of the adhesion layer **202** and the sacrificial layer **201** are different, the adhesion between the adhesion layer **202** and the semiconductor epitaxial stack **3** is different from the adhesion between the sacrificial layer **201** and the semiconductor epitaxial stack **3**. In this embodiment, the adhesion between the adhesion layer **202** and the semiconductor epitaxial stack **3** is larger than the adhesion between the sacrificial layer **201** and the semiconductor epitaxial stack **3**.

The semiconductor epitaxial stack **3** comprises a first semiconductor layer **301** having a first type conductivity, a converting unit **302**, and a second semiconductor layer **303** having a second type conductivity sequentially formed on the growth substrate **102**. The first semiconductor layer **301** and the second semiconductor layer **303** both are single-layer structure or multi-layer structure (multi-layer means two or more than two layers). The first semiconductor layer **301** and the second semiconductor layer **303** have different conductive types, different electrical types and different polarities, or are doped with different elements for providing electrons or holes. When the first semiconductor layer **301** is p-type semiconductor, the second semiconductor layer **303** is n-type semiconductor, of which the electrical type is different from that of the p-type semiconductor. On the contrary, when the first semiconductor layer **301** is n-type semiconductor, the second semiconductor layer **303** is p-type semiconductor. The converting unit **302** is formed between the first semiconductor layer **301** and the second semiconductor layer **303**. The converting unit **302** is able to mutually convert light into electrical power or electrical power into light. The semiconductor epitaxial stack **3** can be further adopted in a semiconductor device, equipment, product or circuit for mutually converting light into electrical power or electrical power into light. Specifically, the semiconductor epitaxial stack **3** can further form a light-emitting diode (LED), a laser diode (LD), a solar cell or be adopted in a display. Taking the light-emitting diode (LED) as an example, the wavelength of the emitted light can be adjusted by adjusting the combination of one layer or multiple layers of the semiconductor epitaxial stack **3**. The material of the semiconductor epitaxial stack **3** comprises aluminum gallium indium phosphide (AlGaInP) series, aluminum gallium indium nitride (AlGaInN) series or zinc oxide (ZnO) series. The structure of the converting unit **302** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH) or multi-quantum well (MWQ). Specifically, the converting unit **302** can be intrinsic, p-type or n-type semiconductor. When an electrical current passes through the semiconductor epitaxial stack **3**, the converting unit **302** is able to emit a light. As the converting unit **302** is made of aluminum gallium indium phosphide (AlGaInP) series, the light emitted from the converting unit **302** is amber series such as red, orange and yellow. As the converting unit **302** is made of aluminum gallium indium nitride (AlGaInN) series, the light emitted from the converting unit **302** is blue or green.

In the next step, as shown in FIG. **1**D, the growth substrate **102** is separated from the semiconductor epitaxial stack **3** and a surface **3011** of the semiconductor epitaxial stack **3** is exposed. The method of separating the growth substrate **102** comprises irradiation method which uses a laser to penetrate the growth substrate **102** and to irradiate the interface between the growth substrate **102** and the semiconductor epitaxial stack **3** for separating the semiconductor epitaxial stack **3** from the growth substrate **102**. In addition, wet etching method can be applied to directly remove the growth substrate **102** or remove an interlayer (not shown) between the growth substrate **102** and the semiconductor epitaxial stack **3** for separating the semiconductor epitaxial stack **3** and the growth substrate **102**. Besides, the interlayer between the growth substrate **102** and the semiconductor epitaxial stack **3** can be removed by using vapor etch method in high temperature for separating the semiconductor epitaxial stack **3** and the growth substrate **102**.

As shown in FIG. **1**E, a patterned adhesion medium **4** corresponding to the sacrificial layer **201** is formed on the surface **3011** of the semiconductor epitaxial stack **3**, wherein the method of forming the patterned adhesion medium **4** comprises forming a layer of adhesion medium on the surface **3011** and then using photolithography method or etching method to pattern the layer of adhesion medium to form the patterned adhesion medium **4**, wherein the photolithography method and the patterned etching method are general semiconductor producing processes. The material of the patterned adhesion medium **4** comprises organic material or inorganic material, wherein the organic material comprises acrylic acid, unsaturated polyester, epoxy, oxetane, vinyl ether, nylon, PP, PBT, PPO, PC, ABS, PVC or BCB, and the inorganic material comprises metal such as Ti, Au, Be, W, Al, Ge, Cu and combination thereof, oxide such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO and $SiO_x$, or nitride such as $SiN_x$.

In the next step, as shown in FIG. **1**F, the semiconductor epitaxial stack **3** and the adhesion structure **2** are patterned to reveal the surface **1011**, so a plurality of semiconductor epitaxial stacks is formed, wherein the multiple semiconductor epitaxial stacks are separated. The multiple semiconductor epitaxial stacks comprise a first semiconductor epitaxial stack **31** and a second semiconductor epitaxial stack **32**, wherein the first semiconductor epitaxial stack **31** has the adhesion medium **4** thereon and the second semiconductor epitaxial stack **32** has no the adhesion medium **4** on the surface **3011**. The method of patterning the semiconductor epitaxial stack **3** and the adhesion structure **2** comprises wet etching or dry etching. In this embodiment, dry etching method is applied to make an interval w between the first

semiconductor epitaxial stack **31** and the second semiconductor epitaxial stack **32** as small as possible to prevent epitaxial stack of the semiconductor epitaxial stack **3** from being removed excessively. In this embodiment, the interval w is between 1 μm and 10 μm, or preferably about 5 μm.

In the next step, as shown in FIG. **1**G, a picking unit **103** is provided to stick to the adhesion medium **4** by heating, pressing, or using stickiness of the picking unit **103**. The picking unit **103** comprises electrically-conductive material such as electrically-conductive substrate and printed circuit board, wherein the electrically-conductive substrate comprises semiconductor such as Si, GaAs, GaN, AlN and SiC; oxide such as ZnO; metal; or the combination thereof, and the printed circuit board comprises single-sided printed circuit board, double-sided printed circuit board, multi-layer printed circuit board, or flexible printed circuit board; or electrically-insulated material such as sapphire, diamond, glass, quartz, acryl, AlN, $LiAlO_2$, ceramics and EPS tape. When the EPS tape is used as the picking unit **103**, it is necessary to provide a hard substrate to stick with the EPS tape for supporting the EPS tape and preventing the EPS tape from sticking the surface **3011** of the second semiconductor epitaxial stack **32**. In another embodiment, as shown in FIG. **11**A, the picking unit **103** comprises a flexible substrate **1032** and a supporting structure **1031**, wherein the flexible substrate **1032** comprises polyester resin (PET), polyethylene naphthalate (PEN), or polyimide (PI), and the supporting structure **1031** comprises hard substrate such as sapphire, diamond, glass, quartz and acryl, for supporting the flexible substrate **1032**.

In another embodiment, the patterned adhesion medium **4** is able to be formed on the picking unit **103** in advance. Then, the alignment bonding technology is applied to align the adhesion medium **4** and the first semiconductor epitaxial stack **31** firstly and then bond the adhesion medium **4** and the first semiconductor epitaxial stack **31** by heating and pressing.

In the next step, as shown in FIG. **1**H, when the adhesion between the sacrificial layer **201** and the first semiconductor epitaxial stack **31** is smaller than the adhesion between the adhesion medium **4** and the first semiconductor epitaxial stack **31**, the forces in the opposite directions can be directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the sacrificial layer **201** for preventing the structure of the first semiconductor epitaxial stack **31** from being damaged. For example, when the material of the sacrificial layer **201** is UV dissociated material comprising acrylic acid, unsaturated polyester, epoxy, oxetane, or vinyl ether, the stickiness of the sacrificial layer **201** can be reduced by the irradiation on the sacrificial layer **201** by UV light, and then the forces in the opposite directions are directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the sacrificial layer **201**. When the material of the sacrificial layer **201** is thermoplastic comprising nylon, PP, PBT, PPO, PC, ABS, or PVC, the stickiness of the sacrificial layer **201** can be reduced by heating, and then the forces in the opposite directions are directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the sacrificial layer **201**. When the adhesion medium **4** is made of the material with high stickiness such as BCB, and the sacrificial layer **201** is made of the material with low stickiness, the first semiconductor epitaxial stack **31** and the sacrificial layer **201** can be separated by directly applying the forces in the opposite directions on the picking unit **103** and the adhesion substrate **101** without heating or irradiating the sacrificial layer **201**. The material with low stickiness comprises metal such as Ti, Al and TiW, oxide such as SiOx, or nitride such as SiNx.

Besides, as shown in FIG. **1**I, when the material of the sacrificial layer **201** comprises metal such as Ti, Al, TiW and Ag, or the material with Si such as SiOx, SiNx and poly-Si, the sacrificial layer **201** can be removed by wet etching or vapor etching, and then the forces in the opposite directions are directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the sacrificial layer **201**. In this embodiment, the etchant used in the wet etching process comprises hydrofluoric (HF) acid, and the chemical material used in the vapor etching process comprises hydrofluoric (HF) vapor.

In another embodiment, as mentioned above, the picking unit **103** comprises the flexible substrate **1032** and the supporting structure **1031**. After the first semiconductor epitaxial stack **31** is separated from the sacrificial layer **201**, the flexible substrate **1032** and the supporting structure **1031** are able to be separated to form a flexible display as shown in FIG. **11**B.

## Second Embodiment

FIGS. **2**A to **2**H show the structures corresponding to the steps of a manufacturing process according to the second embodiment. As shown in FIG. **2**A, the difference between this embodiment and the first embodiment lies in the structure of the adhesion structure **2**. In this embodiment, the sacrificial layer **201** is between the surface **1011** of the adhesion substrate **101** and the adhesion layer **202**. Though the other processes shown in FIGS. **2**B to **2**H are the same as the first embodiment, after the first semiconductor epitaxial stacks **31** are formed by the process disclosed in this embodiment, each of the first semiconductor epitaxial stacks **31** has the adhesion layer **202** on a surface **311** of each of the first semiconductor epitaxial stacks **31**.

## Third Embodiment

FIGS. **3**A to **3**H show the structures corresponding to the steps of a manufacturing process according to the third embodiment. As shown in FIG. **3**A, the sacrificial layer **201** and the adhesion layer **202** are formed on the surface **311** of the semiconductor epitaxial stack **3** and the surface **1011** of the adhesion substrate **101** respectively in advance. Then, as shown in FIG. **3**B, the semiconductor epitaxial stack **3** and the adhesion substrate **101** are bonded through the sacrificial layer **201** and the adhesion layer **202** by heating and pressing to form the adhesion structure **2**. Because the material of the adhesion layer **202** comprises BCB, the sacrificial layer **201** extrudes the material of the adhesion layer **202** between the sacrificial layer **201** and the adhesion substrate **101** during the bonding process. Therefore, the thickness of the adhesion layer **202** between the sacrificial layer **201** and the adhesion substrate **101** is smaller than the thickness of the adhesion layer **202** between the semiconductor epitaxial stack **3** and the adhesion substrate **101**. The difference between this embodiment and the first embodiment lies in the structure of the adhesion structure **2**. In this embodiment, the sacrificial layer **201** is on the adhesion layer **202** and does not contact the surface **1011** of the adhesion substrate **101**. The other processes shown in FIGS. **3**B to **3**H are the same as the first embodiment.

## Fourth Embodiment

FIGS. **4**A to **4**C show the structures according to the fourth embodiment. As shown in FIG. **4**A, the difference between this embodiment and the third embodiment is that the surface **311** of each of the first semiconductor epitaxial stacks **31** contacts the patterned sacrificial layer **201** and the adhesion layer **202**. Alternatively, as shown in FIG. **4**B, the difference between this embodiment and the first embodiment can be that the surface **311** of each of the first semiconductor epitaxial stacks **31** contacts the patterned sacrificial layer **201** and the adhesion layer **202**. Alternatively, as shown in FIG. **4**C, the difference between this embodiment and the second embodiment can be that each of the patterned sacrificial layers **201** corresponding to the first semiconductor epitaxial stacks **31** is covered by the adhesion layer **202** and adhered to the adhesion substrate **101**. A growth substrate **102** is provided and a semiconductor epitaxial stack **3** is formed on the growth substrate **102** by epitaxial growth. Then, the growth substrate **102** and the semiconductor epitaxial stack **3** are adhered to the surface **1011** for being bonded with the adhesion substrate **101** through the adhesion structure **2**

## Fifth Embodiment

FIGS. **5**A to **5**G show the structures corresponding to the steps of a manufacturing process according to the fifth embodiment. As shown in FIG. **5**A, according to the process for manufacturing the optoelectronic device of the application, an adhesion substrate **101** with a surface **1011** is provided, and an adhesion structure **2** is formed on the surface **1011**, wherein the adhesion structure **2** has a thickness t. In this embodiment, the thickness t is between 1 μm and 10 μm, or preferably between 2 μm and 6 μm. The adhesion substrate **101** comprises an electrically insulated substrate or an electrically-conductive substrate. The material of electrically-insulated substrate comprises sapphire, diamond, glass, quartz, acryl, AlN, $LiAlO_2$ or ceramics; the material of electrically-conductive substrate comprises semiconductor such as Si, GaAs, SiC, GaN and AlN; oxide such as ZnO; metal material; or the combination thereof. The adhesion structure **2** comprises organic material or inorganic material, wherein the organic material comprises acrylic acid, Unsaturated polyester, epoxy, oxetane, vinyl ether, nylon, PP, PBT, PPO, PC, ABS, PVC or BCB; the inorganic material comprises metal such as Ti, Au, Be, W, Al, Ge, Cu and combination thereof, oxide such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO and $SiO_x$, or nitride such as $SiN_x$. The semiconductor epitaxial stack **3** comprises a first semiconductor layer **301** having a first type conductivity, a converting unit **302**, and a second semiconductor layer **303** having a second type conductivity sequentially formed on the growth substrate **102**. The first semiconductor layer **301** and the second semiconductor layer **303** both are single-layer structure or multi-layer structure (multi-layer means two or more than two layers). The first semiconductor layer **301** and the second semiconductor layer **303** have different conductive types, different electrical types, different polarities, or are doped with different elements for providing electrons or holes. When the first semiconductor layer **301** is p-type semiconductor, the second semiconductor layer **303** is n-type semiconductor, of which the electrical type is different from that of the p-type semiconductor. On the contrary, when the first semiconductor layer **301** is n-type semiconductor, the second semiconductor layer **303** is p-type semiconductor. The converting unit **302** is formed between the first semiconductor layer **301** and the second semiconductor layer **303**. The converting unit **302** is able to mutually convert light into electrical power or electrical power into light. The semiconductor epitaxial stack **3** can further be adopted in a semiconductor device, equipment, product or circuit for mutually converting light into electrical power or electrical power into light. Specifically, the semiconductor epitaxial stack **3** can further form a light-emitting diode (LED), a laser diode (LD), a solar cell or be adopted in a display. Taking the light-emitting diode (LED) as an example, the wavelength of the light emitted can be adjusted by adjusting the combination of one layer or multiple layers of the semiconductor epitaxial stack **3**. The material of the semiconductor epitaxial stack **3** comprises aluminum gallium indium phosphide (AlGaInP) series, aluminum gallium indium nitride (AlGaInN) series or zinc oxide (ZnO) series. The structure of the converting unit **302** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH) or multi-quantum well (MWQ). Specifically, the converting unit **302** can be intrinsic, p-type, or n-type semiconductor. When an electrical current passes through the semiconductor epitaxial stack **3**, the converting unit **302** is able to emit light. As the converting unit **302** is made of aluminum gallium indium phosphide (AlGaInP) series, the light emitted from the converting unit **302** is amber series such as red, orange, and yellow. As the converting unit **302** is made of aluminum gallium indium nitride (AlGaInN) series, the light emitted from the converting unit **302** is blue or green.

In another embodiment, the adhesion structure **2** is formed on a surface **3012** of the semiconductor epitaxial stack **3** in advance, and the growth substrate **102** and the semiconductor epitaxial stack **3** are adhered to the surface **1011** for being bonded with the adhesion substrate **101** through the adhesion structure **2**.

In the next step, as shown in FIG. **5**B, the growth substrate **102** is separated from the semiconductor epitaxial stack **3** and a surface **3011** of the semiconductor epitaxial stack **3** is exposed. The method of separating the growth substrate **102** comprises irradiation method which uses a laser penetrating the growth substrate **102** to irradiate the interface between the growth substrate **102** and the semiconductor epitaxial stack **3** for separating the semiconductor epitaxial stack **3** and the growth substrate **102**. In addition, wet etching method can be applied to directly remove the growth substrate **102** or remove an interlayer (not shown) between the growth substrate **102** and the semiconductor epitaxial stack **3** for separating the semiconductor epitaxial stack **3** and the growth substrate **102**. Besides, the interlayer between the growth substrate **102** and the semiconductor epitaxial stack **3** can be removed by using vapor etch method in high temperature for separating the semiconductor epitaxial stack **3** and the growth substrate **102**.

In the next step, as shown in FIG. **5**C, a patterned adhesion medium **4** corresponding to the sacrificial layer **201** is formed on the surface **3011** of the semiconductor epitaxial stack **3**, wherein the method of forming the patterned adhesion medium **4** comprises forming a layer of adhesion medium layer on the surface **3011** and, then, using photolithography method or etching method to pattern the layer of adhesion medium layer to form the patterned adhesion medium **4**, wherein the photolithography method and the patterned etching method are generally semiconductor producing processes. The material of the patterned adhesion medium **4** comprises organic material or inorganic material, wherein the organic material comprises acrylic acid, unsaturated polyester, epoxy, oxetane, vinyl ether,

nylon, PP, PBT, PPO, PC, ABS, PVC or BCB, and the inorganic material comprises metal such as Ti, Au, Be, W, Al, Ge, Cu and combination thereof, oxide such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO and $SiO_x$, or nitride such as $SiN_x$.

In the next step, as shown in FIG. **5**D, the semiconductor epitaxial stack **3** and the adhesion structure **2** are patterned to reveal the surface **1011** so a plurality of semiconductor epitaxial stacks is formed, wherein the multiple semiconductor epitaxial stacks are separated. The multiple semiconductor epitaxial stacks comprise a first semiconductor epitaxial stack **31** and a second semiconductor epitaxial stack **32**. FIG. **5**E shows the top-view of the first semiconductor epitaxial stacks **31** and the second semiconductor epitaxial stacks **32** in FIG. **5**D. In this embodiment, the area of the first semiconductor epitaxial stack **31** is smaller than the area of the second semiconductor epitaxial stacks **32**. And, each of the first semiconductor epitaxial stacks **31** has the adhesion medium **4** thereon, and the second semiconductor epitaxial stack **32** has no the adhesion medium **4** on the surface **3011**. The method of patterning the semiconductor epitaxial stack **3** and the adhesion structure **2** comprises wet etching or dry etching. In this embodiment, dry etching method is applied to make an interval w between the first semiconductor epitaxial stack **31** and the second semiconductor epitaxial stack **32** as small as possible to prevent epitaxial stack of the semiconductor epitaxial stack **3** from being removed excessively. In this embodiment, the interval w is between 1 μm and 10 μm, or preferably about 5 μm.

In the next step, as shown in FIG. **5**F, a picking unit **103** is provided to stick the adhesion medium **4** by heating, pressing, or using the stickiness of the picking unit **103**. The picking unit **103** comprises electrically-conductive material, such as electrically-conductive substrate and printed circuit board, wherein the electrically-conductive substrate comprises semiconductor such as Si, GaAs, SiC, GaN, and AlN; oxide such as ZnO; metal or the combination thereof, and the printed circuit board comprises single-sided printed circuit board, double-sided printed circuit board, multi-layers printed circuit board, or flexible printed circuit board; or electrically-insulated material such as sapphire, diamond, glass, quartz, acryl, $LiAlO_2$, ceramics substrate and EPS tape. When the EPS tape is used as the picking unit **103**, it is necessary to provide a hard substrate to stick the EPS tape for supporting the EPS tape and for preventing the EPS tape from sticking the surface **3011** of the second semiconductor epitaxial stack **32**. In another embodiment, as shown in FIG. **11**A, the picking unit **103** comprises a flexible substrate **1032** and a supporting structure **1031**, wherein the flexible substrate **1032** comprises polyester resin (PET), polyethylene naphthalate (PEN), or polyimide (PI), and the supporting structure **1031** comprises hard substrate such as sapphire, diamond, glass, quartz and acryl, for supporting the flexible substrate **1032**.

In another embodiment, the patterned adhesion medium **4** is able to be formed on the picking unit **103** in advance. Then, the alignment bonding technology is applied to align the adhesion medium **4** and the first semiconductor epitaxial stack **31** firstly and to bond the adhesion medium **4** and the first semiconductor epitaxial stack **31** by heating and pressing for forming the structure shown in FIG. **5**F.

In the next step, as shown in FIG. **5**G, the adhesion structure **2** is etched by using wet etching or vapor etching. The etching time of the wet etching or the vapor etching is limited to make the first semiconductor epitaxial stack **31** being totally separated from the adhesion substrate **101** and a portion of the adhesion structure **2** remaining between the second semiconductor epitaxial stack **32** and adhesion substrate **101** to support the second semiconductor epitaxial stack **32**.

In another embodiment, as mentioned above, the picking unit **103** comprises the flexible substrate **1032** and the supporting structure **1031**. After the first semiconductor epitaxial stack **31** is separated from the sacrificial layer **201**, the flexible substrate **1032** and the supporting structure **1031** are able to be separated to form a flexible display, as shown in FIG. **11**B.

## Sixth Embodiment

FIGS. **6**A to **6**H show the structures corresponding to the steps of a manufacturing process according to the sixth embodiment. As shown in FIG. **6**A, according to the process for manufacturing the optoelectronic device of the application, an adhesion substrate **101** is provided and the adhesion substrate **101** has a surface **1011** and a surface **1012** opposite to the surface **1011**. The adhesion substrate **101** has a hole **110** passing from the surface **1011** to the surface **1012**. FIG. **6**B shows the top-view of the adhesion substrate **101**, wherein FIG. **6**A shows the cross-sectional diagram along the dotted line CC' of FIG. **6**B. The adhesion substrate **101** comprises an electrically-insulated substrate or an electrically-conductive substrate. The material of electrically-insulated substrate comprises sapphire, diamond, glass, quartz, acryl, $LiAlO_2$, or ceramics; the material of electrically-conductive substrate comprises semiconductor such as Si, GaAs, SiC, GaN, AlN; oxide such as ZnO; metal material or the combination thereof.

In the next step, as shown in FIG. **6**C, a growth substrate **102** is provided and a semiconductor epitaxial stack **3** is formed on the growth substrate **102** by epitaxial growth. Then, the growth substrate **102** and the semiconductor epitaxial stack **3** are adhered to the surface **1011** for being bonded with the adhesion substrate **101** through the adhesion structure **2**, wherein the holes **110** reveal a portion of the adhesion structure **2**. In this embodiment, the adhesion structure **2** can be formed on the surface **3012** of the semiconductor epitaxial stack **3** in advance, and then, the growth substrate **102** and the semiconductor epitaxial stack **3** are adhered to the surface **1011** for being bonded with the adhesion substrate **101** through the adhesion structure **2**.

The adhesion structure **2** has a thickness t between 1 μm and 10 μm, or preferably between 2 μm and 6 μm. The adhesion structure **2** comprises organic material or inorganic material, wherein the organic material comprises acrylic acid, unsaturated polyester, epoxy, oxetane, vinyl ether, nylon, PP, PBT, PPO, PC, ABS, PVC, or BCB, and the inorganic material comprises metal such as Ti, Au, Be, W, Al, Ge, Cu and combination thereof; oxide such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO and $SiO_x$; or nitride such as $SiN_x$. The semiconductor epitaxial stack **3** comprises a first semiconductor layer **301** having a first type conductivity, a converting unit **302**, and a second semiconductor layer **303** having a second type conductivity sequentially formed on the growth substrate **102**. The first semiconductor layer **301** and the second semiconductor layer **303** both are single-layer structure or multi-layer structure (multi-layer means two or more than two layers). The first semiconductor layer **301** and the second semiconductor layer **303** have different conductive types, different electrical types, and different polarities, or are doped with different elements for providing electrons or holes. When the first semiconductor layer **301** is p-type semiconductor, the second semiconductor layer **303** is n-type semiconductor, of which the electrical

type is different from that of the p-type semiconductor. On the contrary, when the first semiconductor layer **301** is n-type semiconductor, the second semiconductor layer **303** is p-type semiconductor. The converting unit **302** is formed between the first semiconductor layer **301** and the second semiconductor layer **303**. The converting unit **302** is able to convert light into electrical power or electrical power into light mutually. The semiconductor epitaxial stack **3** can be further adopted in a semiconductor device, equipment, product or circuit for mutually converting light into electrical power or electrical power into light. Specifically, the semiconductor epitaxial stack **3** can further form a light-emitting diode (LED), a laser diode (LD), a solar cell or be adopted in a display. Taking the light-emitting diode (LED) as an example, the wavelength of the light emitted can be adjusted by adjusting the combination of one layer or multiple layers of the semiconductor epitaxial stack **3**. The material of the semiconductor epitaxial stack **3** comprises aluminum gallium indium phosphide (AlGaInP) series, aluminum gallium indium nitride (AlGaInN) series, or zinc oxide (ZnO) series. The structure of the converting unit **302** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH) or multi-quantum well (MWQ). Specifically, the converting unit **302** can be intrinsic, p-type, or n-type semiconductor. When an electrical current passes through the semiconductor epitaxial stack **3**, the converting unit **302** is able to emit a light. As the converting unit **302** is made of aluminum gallium indium phosphide (AlGaInP) series, the light emitted from the converting unit **302** is amber series, such as red, orange and yellow. As the converting unit **302** is made of aluminum gallium indium nitride (AlGaInN) series, the light emitted from the converting unit **302** is blue or green.

In the next step, as shown in FIG. **6**D, the growth substrate **102** is separated from the semiconductor epitaxial stack **3** for revealing a surface **3011** of the semiconductor epitaxial stack **3**, and a support structure **5** is formed on and conformally covers the surface **1012** of the adhesion substrate **101**, a wall surface **1101** of the holes **110** and a portion of the adhesion structure **2** exposed from the holes **110**. In the embodiment, the method of separating the growth substrate **102** comprises the methods mentioned in the first embodiment. The material of the support structure **5** comprises organic material or inorganic material, wherein the organic material comprises UV dissociated glue or thermoplastic, and the inorganic material, comprises metal, oxide or nitride, wherein UV dissociated glue comprises acrylic acid, unsaturated polyester, epoxy, oxetane or vinyl ether, the thermoplastic comprises Nylon, PP, PBT, PPO, PC, ABS or PVC, the metal comprises Ti, Au, Be, W, Al or Ge, the oxide comprises $SiO_x$, and the nitride comprises SiNx.

In the next step, as shown in the FIG. **6**E, a patterned adhesion medium **4** corresponding to the holes **110** is formed on the surface **3011** of the semiconductor epitaxial stack **3**, wherein the method of forming the patterned adhesion medium **4** comprises forming a layer of adhesion medium layer on the surface **3011** and then, using photolithography method or etching method to pattern the layer of adhesion medium layer to form the patterned adhesion medium **4**, wherein the photolithography method and the patterned etching method are generally semiconductor producing processes. The material of the patterned adhesion medium **4** comprises organic material or inorganic material, wherein the organic material comprises acrylic acid, unsaturated polyester, epoxy, oxetane, vinyl ether, nylon, PP, PBT, PPO, PC, ABS, PVC or BCB, and the inorganic material comprises metal such as Ti, Au, Be, W, Al, Ge, Cu and combination thereof, oxide such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO and $SiO_x$, or nitride such as $SiN_x$.

In the next step, as shown in FIG. **6**F, the semiconductor epitaxial stack **3** and the adhesion structure **2** are patterned to reveal the surface **1011**, so a plurality of semiconductor epitaxial stacks is formed, wherein the multiple semiconductor epitaxial stacks are separated. The multiple semiconductor epitaxial stacks comprise a first semiconductor epitaxial stack **31** and a second semiconductor epitaxial stack **32**, wherein the first semiconductor epitaxial stack **31** has the adhesion medium **4** thereon and the second semiconductor epitaxial stack **32** has no the adhesion medium **4** on the surface **3011**. The method of patterning the semiconductor epitaxial stack **3** and the adhesion structure **2** comprises wet etching or dry etching. In this embodiment, dry etching method is applied to make an interval w between the first semiconductor epitaxial stack **31** and the second semiconductor epitaxial stack **32** as small as possible to prevent epitaxial stack of the semiconductor epitaxial stack **3** from being removed excessively. In this embodiment, the interval w is between 1 μm and 10 μm, or preferably about 5 μm.

In the next step, as shown in FIG. **6**G, a picking unit **103** is provided to stick the adhesion medium **4** by heating, pressing, or using stickiness of the picking unit **103**. The picking unit **103** comprises electrically-conductive material, such as electrically-conductive substrate and printed circuit board, wherein the electrically-conductive substrate comprises semiconductor such as Si, GaAs, SiC, GaN, AlN; oxide such as ZnO; metal or the combination thereof, and the printed circuit board comprises single-sided printed circuit board, double-sided printed circuit board, multi-layers printed circuit board or flexible printed circuit board; or electrically-insulated material, such as sapphire, diamond, glass, quartz, acryl, $LiAlO_2$, ceramics and EPS tape. When the EPS tape is used as the picking unit **103**, it is necessary to provide a hard substrate to stick the EPS tape for supporting the EPS tape and for preventing the EPS tape from sticking the surface **3011** of the second semiconductor epitaxial stack **32**.

In another embodiment, as shown in FIG. **11**A, the picking unit **103** comprises a flexible substrate **1032** and a supporting structure **1031**, wherein the flexible substrate **1032** comprises polyester resin (PET), polyethylene naphthalate (PEN) or polyimide (PI), and the supporting structure **1031** comprises hard substrate such as sapphire, diamond, glass, quartz and acryl, for supporting the flexible substrate **1032**.

In another embodiment, the patterned adhesion medium **4** is able to be formed on the picking unit **103** in advance. Then, the alignment bonding technology is applied to align the adhesion medium **4** and the first semiconductor epitaxial stack **31** firstly and, then, bond the adhesion medium **4** and the first semiconductor epitaxial stack **31** by heating and pressing.

In the next step, as shown in FIG. **6**H, when the material of the support structure **5** is metal such as Ti, Al, TiW and Ag, or the material containing Si, such as $SiO_x$, $SiN_x$ and poly-Si, the support structure **5** can be removed by wet etching or vapor etching, and, then, the forces in the opposite directions are directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the sacrificial layer **201**. In this embodiment, the etchant used in the wet etching process comprises hydrofluoric (HF) acid, and the chemical material used in the vapor etching process comprises hydrofluoric (HF) vapor. When the material of the support structure **5** is UV dissociated material comprising acrylic acid,

unsaturated polyester, epoxy, oxetane or vinyl ether, the adhesion between the support structure **5** and the adhesion structure **2** can be reduced or disappears by using UV light to irradiate the support structure **5**, and, then, the forces in the opposite directions are directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the support structure **5**. When the material of the support structure **5** is thermoplastic comprising nylon, PP, PBT, PPO, PC, ABS or PVC, the adhesion between the support structure **5** and the adhesion structure **2** can be reduced or disappears by heating the support structure **5**, and, then, the forces in the opposite directions are directly applied on the picking unit **103** and the adhesion substrate **101** respectively to separate the first semiconductor epitaxial stack **31** and the support structure **5**.

In another embodiment, as mentioned above, the picking unit **103** comprises the flexible substrate **1032** and the supporting structure **1031**. After the first semiconductor epitaxial stack **31** is separated from the sacrificial layer **201**, the flexible substrate **1032** and the supporting structure **1031** are able to be separated to form a flexible display, as shown in FIG. **11**B.

Seventh Embodiment

FIGS. **7**A to **7**F show the structures corresponding to the steps of a manufacturing process according to the seventh embodiment. The difference between this embodiment and the second embodiment is that the adhesion substrate **101** comprises multiple holes **120** corresponding to each first semiconductor epitaxial stack **31** so that the adhesion between the first semiconductor epitaxial stack **31** and the adhesion substrate **101** in this embodiment is lower than the adhesion between the first semiconductor epitaxial stack **31** and the adhesion substrate **101** in the second embodiment. Therefore, it is easier to separate the first semiconductor epitaxial stack **31** from the adhesion substrate **101** by using mechanical force. Or when the sacrificial layer **201** is removed by wet etching or vapor etching, it needs less time for the etchant comprising hydrofluoric (HF) acid or the chemical material comprising hydrofluoric (HF) vapor to etch the sacrificial layer **201** through the multiple holes **120**.

Eighth Embodiment

FIGS. **8**A to **8**F show the structures corresponding to the steps of a manufacturing process according to the eighth embodiment. The difference between this embodiment and the seventh embodiment is there is no sacrificial layer in the adhesion structure **2** in this embodiment. The adhesion between the first semiconductor epitaxial stack **31** and the adhesion substrate **101** in this embodiment is lower than the adhesion between the first semiconductor epitaxial stack **31** and the adhesion substrate **101**, and the first semiconductor epitaxial stack **31** can be separated from the adhesion substrate **101** by using mechanical force.

Ninth Embodiment

FIGS. **9**A to **9**I show the structures corresponding to the steps of a manufacturing process according to the ninth embodiment. As shown in FIG. **9**A, a growth substrate **102** having a surface **1021** is provided, wherein the surface **1021** is used for growing a semiconductor epitaxial stack thereon in following processes. The material of the growth substrate **102** comprises Ge, GaAs, InP, GaP, sapphire, SiC, Si, $LiAlO_2$, ZnO, GaN, AlN or the combination thereof. A patterned sacrificial layer **601** is formed on the surface **1021** of the growth substrate **102**, wherein the material of the sacrificial layer **601** comprises semiconductor such as AlAs and AlN, or oxide such as $SiO_x$. When the material of the sacrificial layer **601** is semiconductor, the patterned sacrificial layer **601** is formed by Metalorganic Chemical Vapor Deposition (MOCVD) and etching process to pattern the sacrificial layer **601**. When the material of the sacrificial layer **601** is oxide, the patterned sacrificial layer **601** is formed by Physical Vapor Deposition (PVD) or Chemical Vapor Deposition (CVD) and etching process to pattern the sacrificial layer **601**.

In the next step, as shown in FIG. **9**B, a semiconductor layer **304** is formed on the surface **1021** of the growth substrate **102** and covers the sacrificial layer **601**, wherein the material of the semiconductor layer **304** is different from the material of the sacrificial layer **601**. The semiconductor layer **304** comprises a buffer layer (not shown) or a window layer (not shown). The buffer layer is between the growth substrate **102** and the window layer or between the growth substrate **102** and a semiconductor epitaxial stack **3** which is formed in the following processes. In the structure of light-emitting diode, the buffer layer is used for reducing the lattice mismatch between two layers made of different materials. On the other hand, the buffer layer comprises single layer, multiple layers, a combination of two kinds of materials or two separated structures, wherein the material of the buffer layer comprises organic metal, inorganic metal or semiconductor. The buffer layer is able to be used as a reflective layer, thermally conductive layer, electrically-conductive layer, ohmic-contact layer, anti-deformation layer, stress release layer, stress adjusting layer, bonding layer, wavelength converter layer or fixed structure. The window layer is a semiconductor layer with larger thickness for increasing the light extracting efficiency of the semiconductor epitaxial stack **3** and promoting the electrical current lateral spreading, wherein the material of the window layer comprises Al, Ga, In, As, P, N or combination thereof, such as GaN and AlGaInP.

In the next step, as shown in FIG. **9**C, the semiconductor epitaxial stack **3** is formed on the semiconductor layer **304**. The semiconductor epitaxial stack **3** comprises a first semiconductor layer **301** having a first type conductivity, a converting unit **302** and a second semiconductor layer **303** having a second type conductivity sequentially formed on the growth substrate **102**. The first semiconductor layer **301** and the second semiconductor layer **303** both are single-layer structure or multi-layer structure (multi-layer means two or more than two layers). The first semiconductor layer **301** and the second semiconductor layer **303** have different conductive types, different electrical types and different polarities, or are doped with different elements for providing electrons or holes. When the first semiconductor layer **301** is p-type semiconductor, the second semiconductor layer **303** is n-type semiconductor, of which the electrical type is different from that of the p-type semiconductor. On the contrary, when the first semiconductor layer **301** is n-type semiconductor, the second semiconductor layer **303** is p-type semiconductor. The converting unit **302** is formed between the first semiconductor layer **301** and the second semiconductor layer **303**. The converting unit **302** is able to mutually convert light into electrical power or electrical power into light. The semiconductor epitaxial stack **3** can be further adopted in a semiconductor device, equipment, product or circuit for mutually converting light into electrical power or electrical power into light. Specifically, the semi-

conductor epitaxial stack **3** can further form a light-emitting diode (LED), a laser diode (LD), a solar cell or be adopted in a display. Taking the light-emitting diode (LED) as an example, the wavelength of the light emitted can be adjusted by adjusting the combination of one layer or multiple layers of the semiconductor epitaxial stack **3**. The material of the semiconductor epitaxial stack **3** comprises aluminum gallium indium phosphide (AlGaInP) series, aluminum gallium indium nitride (AlGaInN) series, or zinc oxide (ZnO) series. The structure of the converting unit **302** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH) or multi-quantum well (MWQ). Specifically, the converting unit **302** can be intrinsic, p-type or n-type semiconductor. When an electrical current passes through the semiconductor epitaxial stack **3**, the converting unit **302** is able to emit a light. As the converting unit **302** is made of aluminum gallium indium phosphide (AlGaInP) series, the light emitted from the converting unit **302** is amber series such as red, orange and yellow. As the converting unit **302** is made of aluminum gallium indium nitride (AlGaInN) series, the light emitted from the converting unit **302** is blue or green.

In the next step, as shown in FIG. **9**D, a patterned adhesion medium **4** corresponding to the patterned sacrificial layer **601** is formed on the surface **3011** of the semiconductor epitaxial stack **3**, wherein the method of forming the patterned adhesion medium **4** comprises forming a layer of adhesion medium layer on the surface **3011** and, then, using photolithography method or etching method to pattern the layer of adhesion medium layer to form the patterned adhesion medium **4**, wherein the photolithography method and the patterned etching method are generally semiconductor producing processes. The material of the patterned adhesion medium **4** comprises organic material or inorganic material, wherein the organic material comprises acrylic acid, unsaturated polyester, epoxy, oxetane, vinyl ether, nylon, PP, PBT, PPO, PC, ABS, PVC or BCB, and the inorganic material comprises metal such as Ti, Au, Be, W, Al, Ge, Cu and combination thereof; oxide such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO and $SiO_x$; or nitride such as $SiN_x$.

In the next step, as shown in FIG. **9**E, the semiconductor epitaxial stack **3** and the semiconductor layer **304** are patterned to reveal the surface **1011**, so a plurality of semiconductor epitaxial stacks is formed, wherein the multiple semiconductor epitaxial stacks are separated. The multiple semiconductor epitaxial stacks comprise a first semiconductor epitaxial stack **31** and a second semiconductor epitaxial stack **32**, wherein the first semiconductor epitaxial stack **31** has the adhesion medium **4** thereon and the second semiconductor epitaxial stack **32** does not have the adhesion medium **4** on the surface **3011**. The method of patterning the semiconductor epitaxial stack **3** and the adhesion structure **2** comprises wet etching or dry etching. In this embodiment, dry etching method is applied to make an interval w between the first semiconductor epitaxial stack **31** and the second semiconductor epitaxial stack **32** as small as possible to prevent epitaxial stack of the semiconductor epitaxial stack **3** from being removed excessively. In this embodiment, the interval w is between 1 μm and 10 μm, or preferably about 5 μm. In this embodiment, the sacrificial layer **601** is between the first semiconductor epitaxial stack **31** and the growth substrate **102** and the second semiconductor epitaxial stack **32** is directly formed on the growth substrate **102**, so the adhesion between the semiconductor layer **304** and the sacrificial layer **601** can be smaller than the adhesion between the semiconductor layer **304** and the growth substrate **102** by controlling the processing condition of forming the semiconductor layer **304** or by applying different materials for the sacrificial layer **601** and the semiconductor layer **304**, wherein the material of the sacrificial layer **601** comprises oxide.

In the next step, as shown in FIG. **9**F, a picking unit **103** is provided to stick the adhesion medium **4** by heating, pressing or using stickiness of the picking unit **103**. The picking unit **103** comprises electrically-conductive material such as electrically-conductive substrate and printed circuit board, wherein the electrically-conductive substrate comprises semiconductor such as Si, GaAs, SiC, GaN, AlN; oxide such as ZnO; metal or the combination thereof, and the printed circuit board comprises single-sided printed circuit board, double-sided printed circuit board, multi-layers printed circuit board or flexible printed circuit board; or electrically-insulated material such as sapphire, diamond, glass, quartz, acryl, $LiAlO_2$, ceramics, and EPS tape.

In another embodiment, as shown in FIG. **11**A, the picking unit **103** comprises a flexible substrate **1032** and a supporting structure **1031**, wherein the flexible substrate **1032** comprises polyester resin (PET), polyethylene naphthalate (PEN) or polyimide (PI), and the supporting structure **1031** comprises hard substrate such as sapphire, diamond, glass, quartz, and acryl for supporting the flexible substrate **1032**.

In another embodiment, the patterned adhesion medium **4** is able to be formed on the picking unit **103** in advance. Then, the alignment bonding technology is applied to align the adhesion medium **4** and the first semiconductor epitaxial stack **31** firstly and, then, bond the adhesion medium **4** and the first semiconductor epitaxial stack **31** by heating and pressing.

In the next step, as shown in FIG. **9**G, when the sacrificial layer **601** is made of $SiO_x$ or AlAs, the sacrificial layer **601** can be removed by wet etching or vapor etching, and then the forces in the opposite directions are directly applied on the picking unit **103** and the growth substrate **102** respectively to separate the first semiconductor epitaxial stack **31** and the sacrificial layer **601**. In this embodiment, the etchant used in the wet etching process comprises hydrofluoric (HF) acid, and the chemical material used in the vapor etching process comprises hydrofluoric (HF) vapor. In another embodiment, as shown in FIGS. **9**H and **9**I, when the sacrificial layer **601** is not made of semiconductor such as $SiO_x$, a pore **602** between the semiconductor layer **304** and the sacrificial layer **601**, which decreases the contact area between the semiconductor layer **304** and the sacrificial layer **601**, can be formed by controlling the temperature and pressure in the phase of lateral epitaxial growth during epitaxial growth of the semiconductor layer **304**. Then, the forces in the opposite directions can be directly applied on the picking unit **103** and the growth substrate **102** respectively to directly separate the first semiconductor epitaxial stack **31** and the sacrificial layer **601**.

In another embodiment, as shown in FIG. **11**A, the picking unit **103** comprises a flexible substrate **1032** and a supporting structure **1031**, wherein the flexible substrate **1032** comprises polyester resin (PET), polyethylene naphthalate (PEN) or polyimide (PI), and the supporting structure **1031** comprises hard substrate such as sapphire, diamond, glass, quartz and acryl, for supporting the flexible substrate **1032**.

Tenth Embodiment

FIGS. **10**A to **10**C show the structures corresponding to the steps of a manufacturing process according to the tenth

embodiment. The difference between the tenth embodiment and the ninth embodiment is that the adhesion medium **4** is on the second semiconductor epitaxial stack **32** and the first semiconductor epitaxial stack **31** exposes the surface **3011**. As shown in FIG. **10**C, when the semiconductor layer **304** is made of GaN, the sacrificial layer **601** is made of AlN and the growth substrate **102** is a transparent substrate, a laser **7** can irradiate on the semiconductor layer **304** and the sacrificial layer **601** from a surface **1022** of the growth substrate **102** opposite to the semiconductor layer **304** and the sacrificial layer **601** for separating the semiconductor layer **304** of the second semiconductor epitaxial stack **32** from the growth substrate **102**, wherein the energy of the laser **7** is larger than the bandgap of GaN and smaller than the bandgap of AlN. Then, the forces in the opposite directions can be directly applied on the picking unit **103** and the growth substrate **102** respectively to directly separate the second semiconductor epitaxial stack **32** from the growth substrate **102**.

Although the present application has been explained above, it is not the limitation of the range, the sequence in practice, the material in practice, or the method in practice. Any modification or decoration for present application is not detached from the spirit and the range of such.

What is claimed is:

**1**. A method of selectively transferring semiconductor devices, comprising the steps of:

step a: providing a substrate having a first surface and a second surface;

step b: providing a plurality of semiconductor epitaxial stacks on the first surface, wherein each of the plurality of semiconductor epitaxial stacks comprises a first semiconductor epitaxial stack and a second semiconductor epitaxial stack, and the first semiconductor epitaxial stack is apart from the second semiconductor epitaxial stack, and wherein an adhesion between the first semiconductor epitaxial stack and the substrate is different from an adhesion between the second semiconductor epitaxial stack and the substrate; and

step c: selectively separating the first semiconductor epitaxial stack or the second semiconductor epitaxial stack from the substrate.

**2**. The method of selectively transferring semiconductor devices according to claim **1**, wherein the step b comprises providing an adhesion structure for sticking the plurality of semiconductor epitaxial stacks to the first surface.

**3**. The method of selectively transferring semiconductor devices according to claim **2**, wherein the step c comprises providing energy to the adhesion structure for decreasing an adhesion of the adhesion structure.

**4**. The method of selectively transferring semiconductor devices according to claim **3**, wherein the energy comprises ultraviolet, laser or heat.

**5**. The method of selectively transferring semiconductor devices according to claim **2**, wherein the step c comprises removing the adhesion structure.

**6**. The method of selectively transferring semiconductor devices according to claim **5**, wherein the step of removing the adhesion structure comprises using vapor etch method to remove the adhesion structure.

**7**. The method of selectively transferring semiconductor devices according to claim **6**, wherein the vapor etch method for removing the adhesion structure comprises using hydrofluoric (HF) vapor to etch the adhesion structure.

**8**. The method of selectively transferring semiconductor devices according to claim **2**, wherein the adhesion structure comprises benzocyclobutene (BCB).

**9**. The method of selectively transferring semiconductor devices according to claim **2**, the adhesion structure comprises an adhesion layer and a sacrificial layer, wherein the sacrificial layer is corresponding to the plurality of first semiconductor epitaxial stacks, and a material of the sacrificial layer is different from a material of the adhesion layer.

**10**. The method of selectively transferring semiconductor devices according to claim **9**, wherein the adhesion layer is formed between the sacrificial layer and the first semiconductor epitaxial stack, and the sacrificial layer contacts the first surface.

**11**. The method of selectively transferring semiconductor devices according to claim **9**, wherein the sacrificial layer is formed between the adhesion layer and the first semiconductor epitaxial stack, and the sacrificial layer contacts the first semiconductor epitaxial stack.

**12**. The method of selectively transferring semiconductor devices according to claim **9**, wherein the sacrificial layer contacts the first surface and the first semiconductor epitaxial stack.

**13**. The method of selectively transferring semiconductor devices according to claim **9**, wherein the sacrificial layer comprises metal or oxide.

**14**. The method of selectively transferring semiconductor devices according to claim **9**, wherein a thickness of the sacrificial layer is between 1000 Å and 10 μm.

**15**. The method of selectively transferring semiconductor devices according to claim **2**, further comprising providing a picking unit to stick the first semiconductor epitaxial stack for separating the first semiconductor epitaxial stack and substrate.

**16**. The method of selectively transferring semiconductor devices according to claim **15**, wherein the picking unit comprises EPS tape.

**17**. The method of selectively transferring semiconductor devices according to claim **15**, wherein an adhesion medium is between the first semiconductor epitaxial stack and substrate and the taking unit.

**18**. The method of selectively transferring semiconductor devices according to claim **17**, wherein the picking unit and the second semiconductor epitaxial stack are separated by a gap.

**19**. The method of selectively transferring semiconductor devices according to claim **17**, wherein the adhesion medium comprises electrically-conductive material.

**20**. The method of selectively transferring semiconductor devices according to claim **15**, wherein the picking unit comprises electrically-conductive substrate or printed circuit board.

**21**. The method of selectively transferring semiconductor devices according to claim **15**, wherein the picking unit comprises a supporting structure and a flexible substrate on the supporting structure.

**22**. The method of selectively transferring semiconductor devices according to claim **21**, further comprising a step of separating the flexible substrate and the supporting structure after the step c.

**23**. The method of selectively transferring semiconductor devices according to claim **21**, wherein the flexible substrate comprises polyester resin (PET), polyethylene naphthalate (PEN) or polyimide (PI).

**24**. The method of selectively transferring semiconductor devices according to claim **2**, wherein the step b comprises:

providing a growth substrate;

forming the semiconductor epitaxial stack on the growth substrate;

sticking the semiconductor epitaxial stack to the first surface by the adhesion structure;

removing the growth substrate; and

patterning the semiconductor epitaxial stack and the adhesion structure to form the plurality of semiconductor epitaxial stacks.

**25**. The method of selectively transferring semiconductor devices according to claim **24**, wherein the method of patterning the semiconductor epitaxial stack comprises wet etching or dry etching.

**26**. The method of selectively transferring semiconductor devices according to claim **2**, wherein the substrate comprises a hole corresponding to the first semiconductor epitaxial stack, wherein the hole penetrates from the first surface to the second surface.

**27**. The method of selectively transferring semiconductor devices according to claim **26**, wherein the step b comprises forming a support structure covering the second surface of the substrate, a wall surface of the hole and the adhesion structure.

**28**. The method of selectively transferring semiconductor devices according to claim **27**, wherein a material of the support structure comprises metal, oxide or nitride.

**29**. The method of selectively transferring semiconductor devices according to claim **2**, wherein the substrate comprises multiple holes corresponding to the first semiconductor epitaxial stack, wherein the multiple holes penetrates from the first surface to the second surface.

**30**. The method of selectively transferring semiconductor devices according to claim **1**, wherein an area of the first semiconductor epitaxial stack is smaller than an area of the second semiconductor epitaxial stack.

**31**. The method of selectively transferring semiconductor devices according to claim **5**, wherein the step c comprises controlling a time of removing the adhesion structure such that a portion of the adhesion structure remaining between the second semiconductor epitaxial stack and the structure and the adhesion structure between the first semiconductor epitaxial stack and the substrate being totally removed.

**32**. The method of selectively transferring semiconductor devices according to claim **31**, wherein a method of removing the adhesion structure comprises wet etching or dry etching.

**33**. The method of selectively transferring semiconductor devices according to claim **1**, wherein the step b comprises forming a sacrificial layer on the first surface, forming a semiconductor epitaxial stack on the first surface and covering the sacrificial layer, penetrating the semiconductor epitaxial stack to form the first semiconductor epitaxial stack and the second semiconductor epitaxial stack, wherein the sacrificial layer is between the first semiconductor epitaxial stack and the first surface.

**34**. The method of selectively transferring semiconductor devices according to claim **33**, wherein the sacrificial layer comprises III-V group material.

**35**. The method of selectively transferring semiconductor devices according to claim **34**, wherein the step c comprises removing the sacrificial layer by wet etching.

**36**. The method of selectively transferring semiconductor devices according to claim **33**, wherein the sacrificial layer comprises oxide.

**37**. The method of selectively transferring semiconductor devices according to claim **36**, wherein the method of removing the sacrificial layer comprises wet etching or vapor etching.

**38**. The method of selectively transferring semiconductor devices according to claim **37**, wherein the method of removing the sacrificial layer by wet etching comprises using hydrofluoric (HF) to remove the sacrificial layer.

**39**. The method of selectively transferring semiconductor devices according to claim **37**, wherein the removing the sacrificial layer by vapor etching comprises using hydrofluoric (HF) vapor to remove the sacrificial layer.

**40**. The method of selectively transferring semiconductor devices according to claim **33**, wherein a pore is between the semiconductor epitaxial stack and the sacrificial layer after forming the semiconductor epitaxial stack on the first surface and covering the sacrificial layer of step b.

**41**. The method of selectively transferring semiconductor devices according to claim **39**, wherein the step c comprises separating the first semiconductor epitaxial stack from the substrate by using mechanical force.

**42**. The method of selectively transferring semiconductor devices according to claim **33**, wherein the bandgap of the sacrificial layer is larger than the bandgap of the semiconductor epitaxial stack.

**43**. The method of selectively transferring semiconductor devices according to claim **42**, wherein the step c comprises providing a laser, wherein the laser has an energy larger than the bandgap of the semiconductor epitaxial stack and smaller than the bandgap of the sacrificial layer.

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